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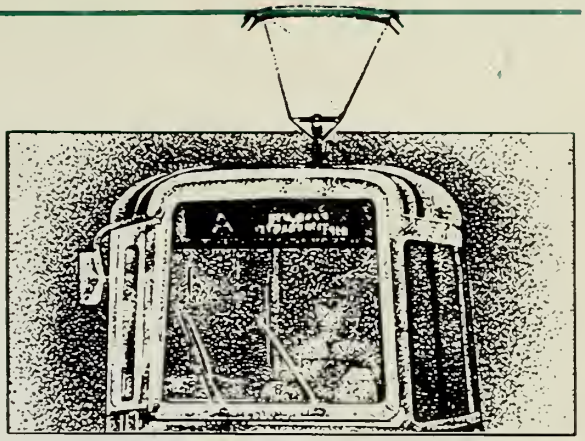

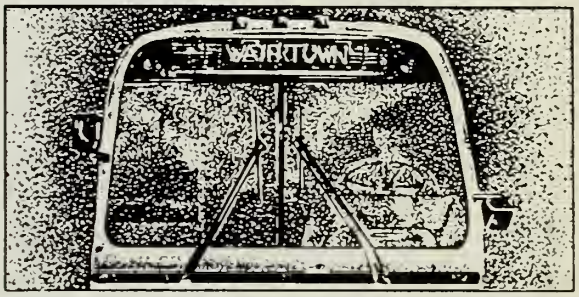

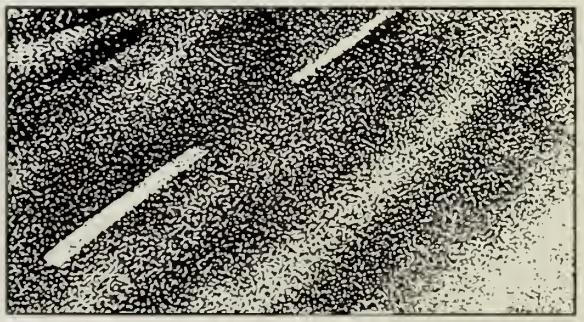

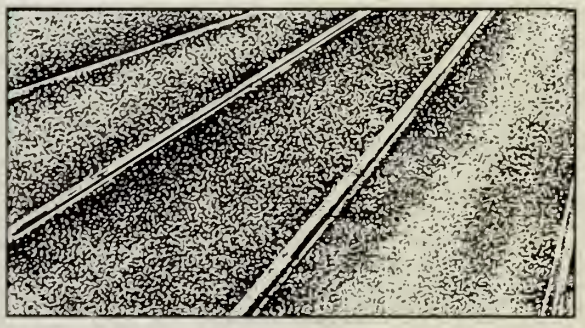

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watertown TROLLEY ANALYSIS

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watertown TROLLEY ANALYSIS

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ABSTRACT

This report summarizes a detailed study of whether to restore trolley service--replaced by bus service in 1969--between Watertown and Park Street Station. Two bus alternatives and six trolley alternatives distinguished by their outer terminals and levels of supplementary bus service were specified. All were evaluated on the basis of ridership, cost, revenue, and transportation system impacts. The major conclusion from this study is that existing bus service is more cost-effective than trolley service would be in this corridor.

Included in the report are descriptions of analysis methods and a summary of findings and conclusions. A separately bound volume of appendices contains detailed descriptions of methods and findings.

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EXECUTIVE SUMMARY

The A route of the Green Line light rail system, from Watertown to the Park Street subway station in Boston, was replaced in 1969 by a bus line from Watertown to Kenmore Square. However, the A-line infrastructure was kept intact for access to the Watertown vehicle maintenance facility. Since 1969, various groups have sought to have trolley service reinstated. Due to the continuous deterioration of the tracks and overhead wire system, the MBTA must decide whether to retain the A-line and upgrade it for restored revenue service, or abandon it altogether. This study was designed to address the issues critical to such a decision.

The major part of the study consisted of comparing ridership, variable operating costs, annualized capital costs, revenue and service characteristics for the public transit service now provided in the A-line corridor with various potential combinations of A-line and bus service. Also examined were the impacts of restored A-line service on other segments of the Green Line, and impacts of A-line and bus service on other traffic.

Five possible outer termini for A-line service were considered: Watertown Square, Newton Corner, Oak Square, Brighton Center and Union Square. The last three were assumed to have feeder bus service between Watertown and the A-line terminal.

Under all A-line scenarios examined except Watertown and Newton Corner termini, there would be a net decrease in mass transit use, because the number of current users who would find the new service unacceptable would exceed the number of current non-users who would find the new service attractive.

At service levels used for cost analysis, A-line service terminating at Watertown would attract about 1000 more riders per day than are currently served by the Watertown-Kenmore (Route 57) and Brighton Center-Downtown Boston (Route 301) bus routes. To justify service frequent enough to attract this demand, Route 301 would have to be discontinued, and most of its riders would have to use the A-line instead of seeking other alternatives. In addition, many of the "new" riders would actually be diverted from existing MBTA routes not explicitly accounted for in the analysis.

The A-line alternatives examined would result in annual variable operating costs 0.2 to 42 percent higher than those of the existing combination of Routes 57 and 301. Annualized capital costs associated with the A-line alternatives would exceed those of the existing services by 36 to 390 percent. The least expensive of the A-line alternatives would terminate at Oak Square, lack Route 301 service and have little feeder bus service from Watertown. Implementation of the alternative would result in a significant ridership loss.

The gross cost per passenger trip for Routes 57 and 301 combined is $0.96, while that for the A-line alternatives would range from $1.17 to $1.66. After accounting for passenger revenue, the net cost per passenger trip for existing services is $0.35, while that for the A-line alternatives would range from $0.67 to $1.08. Existing services generate enough revenue to pay for two-thirds of their variable operating costs; A-line alternatives would pay from one-third to one-half of their variable operating costs.

At the service level used for cost analysis, the A-line would have insufficient peak-period capacity to relieve congestion on the B-line, since the service level was selected to provide just enough capacity for A-line riders. Additional service needed for B-line relief would further increase cost, and could be provided more efficiently on the B-line itself.

Operation of the A-line cars in the Central Subway, at the levels of service used for analysis, would provide little relief for current crowding, as Route 57 transferees are a small percent of total subway riders and because A-line cars would have little capacity for subway boardings at the peak load point. Additional subway shuttle service could be run at much less cost than A-line service.

The segments of the B-line and the Central Subway used by the A-line have capacity to accomodate this service, but the potential for conflicts, and hence unreliability, would rise.

Operation of trolley service on A-line segments west of Packard's Corner would cause increases in traffic delays at major intersections, but elimination of existing bus service would not significantly improve traffic flow in Downtown Boston.

All the CTPS findings point to a conclusion that the existing Routes 57 and 301 are the best alternatives for the A-line corridor.

1 BACKGROUND

1.1 CORRIDOR TRANSIT SERVICES

1.1.1 Previous A-line Service

Service on the A-line or Watertown Trolley line began at Watertown Yard and operated along Galen Street to Newton Corner. From there it operated along Tremont Street to Oak Square in Brighton, then along Washington Street to Brighton Center. The line traversed Cambridge Street into Union Square in Allston, and Brighton Avenue from there to Commonwealth Avenue where it joined the B-line on the Commonwealth Avenue reservation. It then proceeded into the Central Subway and terminated at Park Street Station. Round trip route mileage was 14.9.

As of when the line was terminated in 1969, it was operated with two-car PCC trains on 7.5 minute headways in the peak periods, and with single-cars on 10 minute headways at other times. A total of 34 cars were scheduled for the line out of a total of 266 cars for the entire Green Line.

Between 1947 and 1967, the period for which figures are readily available, the highest one-way inbound weekday surface ridership on the line was 10,900, recorded in 1958. The lowest ridership was 7,000, recorded in 1967, not long before the line's termination.

Service on the A-line was terminated at a time when the MBTA faced a critical shortage of operable trolley cars and when the system was generating an ever-increasing operating deficit. The A-line was singled out as a sensible line to convert to bus operation because it had the lowest ridership of any of the Green Line branches, its long mixed right of way contributed to relatively inefficient use of vehicles and frequent accidents, and it was deemed a relatively unreliable line.

Conversion to a bus line, which occurred on June 21, 1969, was originally planned as an 11 week experiment. The trial period was subsequently extended to a year due to criticism that a summer trial period would be unrepresentative.

Initial findings, released by the MBTA in 1970, showed that since conversion of the line to buses, operating costs had decreased by $325,000 per year, collision accidents had decreased by more than 75 percent and delays had decreased by 90 percent. Moreover, most patrons of the line were found to be in favor of retaining the bus service. On the basis of these findings, the MBTA decided to retain bus service permanently.

For more information on the history of transit services in the A-line corridor, refer to Appendix G.

1.1.2 Existing Transit Services

Replacement bus service for the A-line consists of MBTA Route 57, a local route that follows the A-line alignment between Watertown Yard and Kenmore Station. The route is operated on six minute headways during peak periods, eight and nine minute headways during the midday and 15 minutes at night. Weekend service is provided, with headways ranging from seven to 30 minutes.

MBTA bus Route 301, an express route operated primarily during peak periods, also provides service to much of the former A-line corridor. In its major variation, it originates in Brighton Center, travels west along Washington and Tremont Streets to Newton Corner, serving passengers along the way, and then it operates express along the Massachusetts Turnpike until reaching the Boston CBD where it terminates at Federal and Franklin Streets. It is operated on four minute headways in the AM peak-period and seven minute headways in the PM peak-period. No weekend service is provided.

There are several other MBTA lines in the A-line corridor providing a variety of services. MBTA bus Routes 302 and 304 provide express service between Watertown Square and Newton Corner at their outer ends and Downtown Boston and the Back Bay at their inner ends. Several bus routes provide local service and service to the Red and Green lines. These include MBTA Routes 70 and 71 at Watertown Square, Route 64 at Oak Square and Union Square, Routes 63 and 65 at Brighton Center, and Routes 66 and 86 at Union Square. Finally, the B-line branch of the Green Line provides service to much of the Allston portion of the corridor.

1.2 STUDY BACKGROUND

The MBTA first commissioned CTPS to analyze the technical merits of restoring A-line service in 1985. The CTPS analysis conducted then served as the basis for an MBTA

report entitled Watertown Trolley Study, written by the MBTA Service Planning Office and dated January 1986.

The analysis done by CTPS was limited to estimating the demand, costs and revenues that would be associated with restoring full A-line service from Watertown to Park Street, and to comparing these measures with those corresponding to the replacement bus service. The MBTA Service Planning Office took the analysis results, performed some sensitivity analysis on them, and presented the results in the report cited above. The report served as the basis for an MBTA-sponsored public hearing held on May 14, 1986, at the VFW Hall in Oak Square, Brighton.

During the course of the 1985 study, the MBTA conducted a community participation program. As part of the program, MBTA officials met with several interested citizens, organizations and public officials in order to elicit opinions about the issue of restoring A-line service.

On the basis of testimony received at the public hearing in Brighton and opinions expressed to the MBTA in the community participation program, the MBTA decided to commission CTPS to further analyze the merits of restoring Watertown Trolley service. Specifically, the MBTA directed CTPS to evaluate several issues that were not addressed in the previous work - traffic-related issues - for instance, and to respond to various issues brought up following publication of the Watertown Trolley Study.

This current report, therefore, serves to refine the technical work previously done, to add major elements to it and to document the methods and results as concisely as possible.

It must be stressed at the outset that there are several issues surrounding the question of whether to restore A-line service that are policy issues that can only be dealt with by the MBTA. The CTPS work documented herein is limited to an analysis of various of the technical merits of restoring service, and several of the assumptions underlying the analysis are dictated by MBTA policy.

Specific policy issues that are not within the scope of this analysis include the track and Watertown Yard disposition issues, the Oak Square land disposition issue, MBTA fare policy, and the issue of the degree of public subsidization of transit services in the study corridor versus that in other corridors.

2 ANALYSIS METHOD

The basic approaches used in the first-round 1985 analysis were generally retained. However, modifications were made to some components of some of the approaches, and some underlying assumptions were altered. The chief difference between the first-round work and that done since, though, is that the later work was expanded to include more trolley design scenarios and more sensitivity analysis. Also, the recent work addresses traffic impacts and impacts that restored A-line service would have on the Green Line as a whole. The previous 1985 work and the current work have been integrated and are presented herein as one analysis.

The descriptions of analysis methods in this chapter are meant to be brief. Detailed presentations of the methods, including underlying data, assumptions and calculations, are contained in the series of technical appendices accompanying this report under separate cover. Findings are not presented in this chapter; they follow in Chapter 4.

2.1 DESIGN SCENARIOS

The first step in the analysis involved developing specific design scenarios. Many scenarios were first specified and then some were eliminated due to their impracticality. Several discussions with the MBTA Service Planning Office and public testimony served as the basis for deciding which scenarios to retain for analysis.

The two features distinguishing one trolley alternative from another are its outer terminal and the nature of replacement bus service from the outer terminal westward. The following is a summary of the basic alternatives specified for analysis:

BUS ALTERNATIVES

0. **Base Case:** Maintain existing Routes 57 and 301 as is.
1. **Free Kenmore Transfer:** Existing bus service but with free Route 57/Green Line transfer at Kenmore.

TROLLEY ALTERNATIVES

2. **Watertown Square - Park Street**: Eliminate Routes 57 and 301.
3. **Newton Corner - Park Street**: Eliminate Routes 57 and 301.

4a. **Oak Square - Park Street**: Eliminate Routes 57 and 301; extend Route 64 to Watertown Square.

4b. **Oak Square - Park Street**: Eliminate Route 57; operate Route 301 to Oak Square only; extend Route 64 to Watertown Square.

5. **Brighton Center - Park Street**: Retain Route 301 as is and operate shortened Route 57 to Watertown.
6. **Union Square - Park Street**: Retain Route 301 as is and operated shortened Route 57 to Watertown.

Note that there are two basic bus alternative scenarios. (See Figures 2-1 and 2-2) The first is the do-nothing alternative: it represents current bus service in the corridor. The second differs only in that it specifies a free bus/Green Line transfer at Kenmore Station.

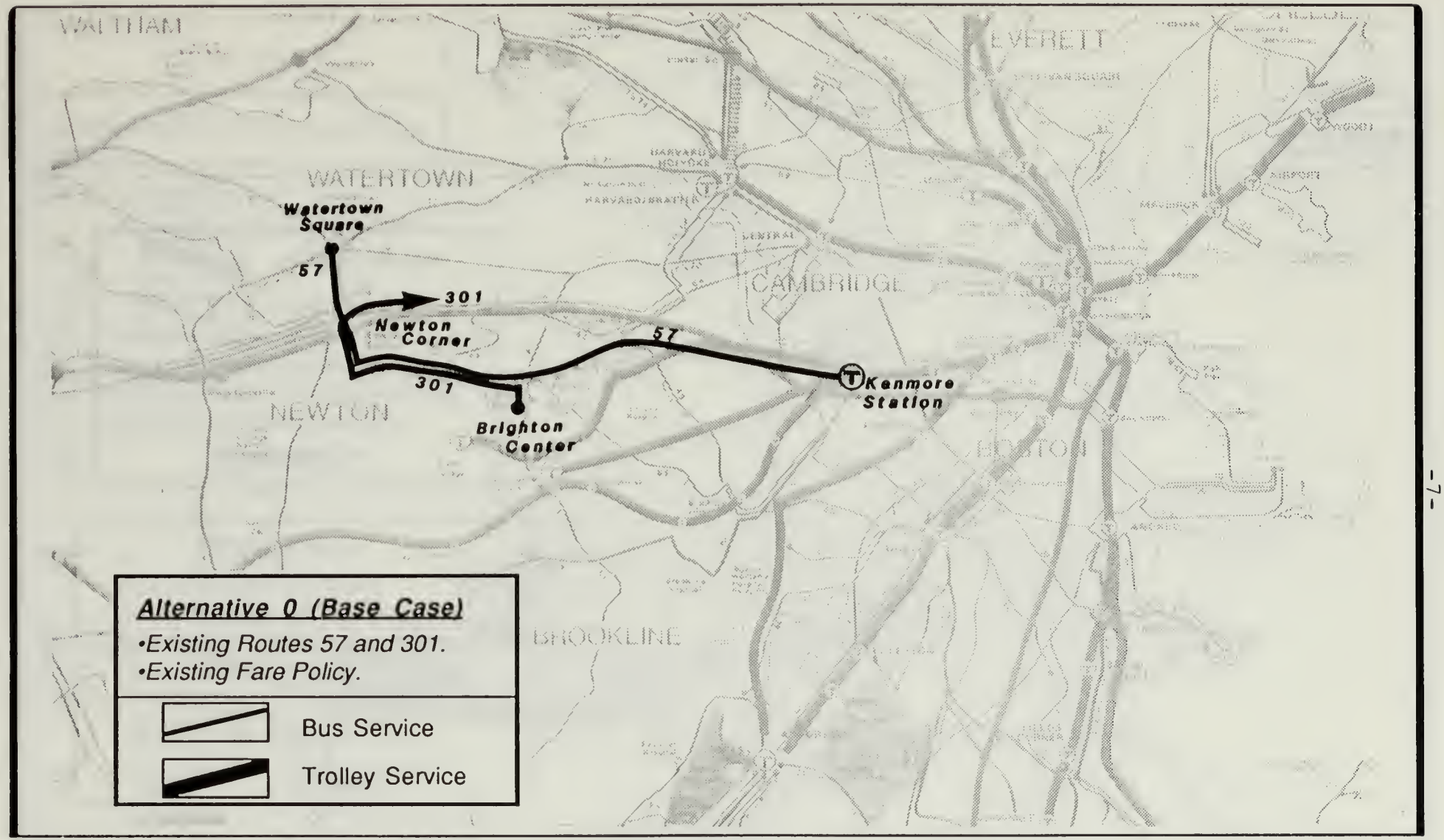
Most of the basic trolley alternatives involve not only provision of trolley service, but of bus service as well. (See Figures 2-3 through 2-8) In three cases, Route 301 is assumed to be retained as is or in a shortened form. In the other cases, it is assumed to be eliminated as redundant. Route 57 is assumed to be eliminated in its present Watertown to Kenmore form in all scenarios, but local service with Route 57-like headways is specified to feed into some of the shorter trolley scenarios. In two cases - the Oak Square outer terminal alternatives - Route 64 is assumed to be extended from Oak Square to Watertown Square to provide replacement bus service. All other current MBTA services are assumed to remain unchanged.

To these basic scenarios, other modifications were made, but in the interests of streamlining the presentation, and because these modifications led to comparable results among the scenarios, they are treated "generically". These include the location of the line's inner terminal at Government Center instead of Park Street and the provision of priority schemes for trolley vehicles.

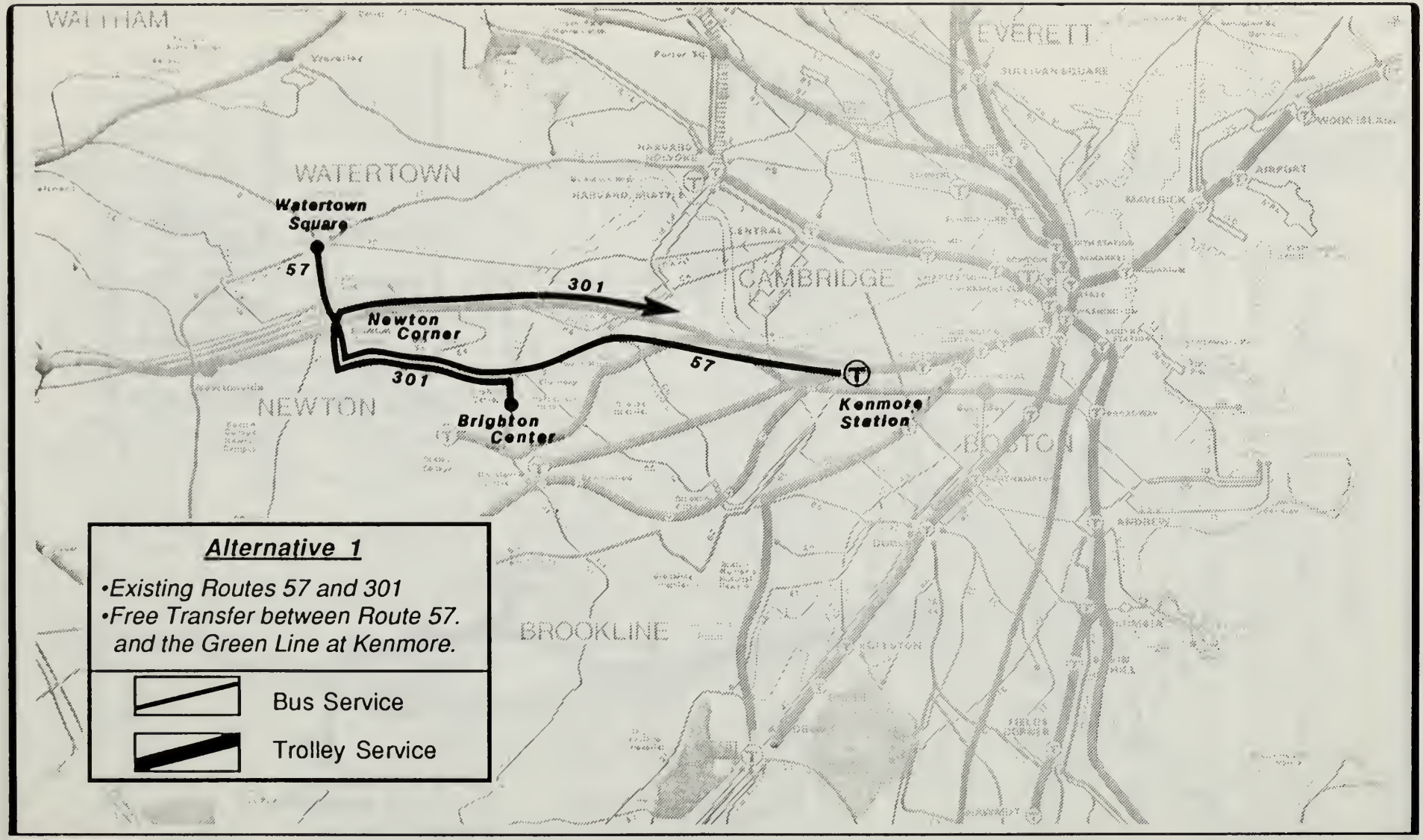
2.2 DEMAND ESTIMATION METHOD

2.2.1 Bus Alternatives

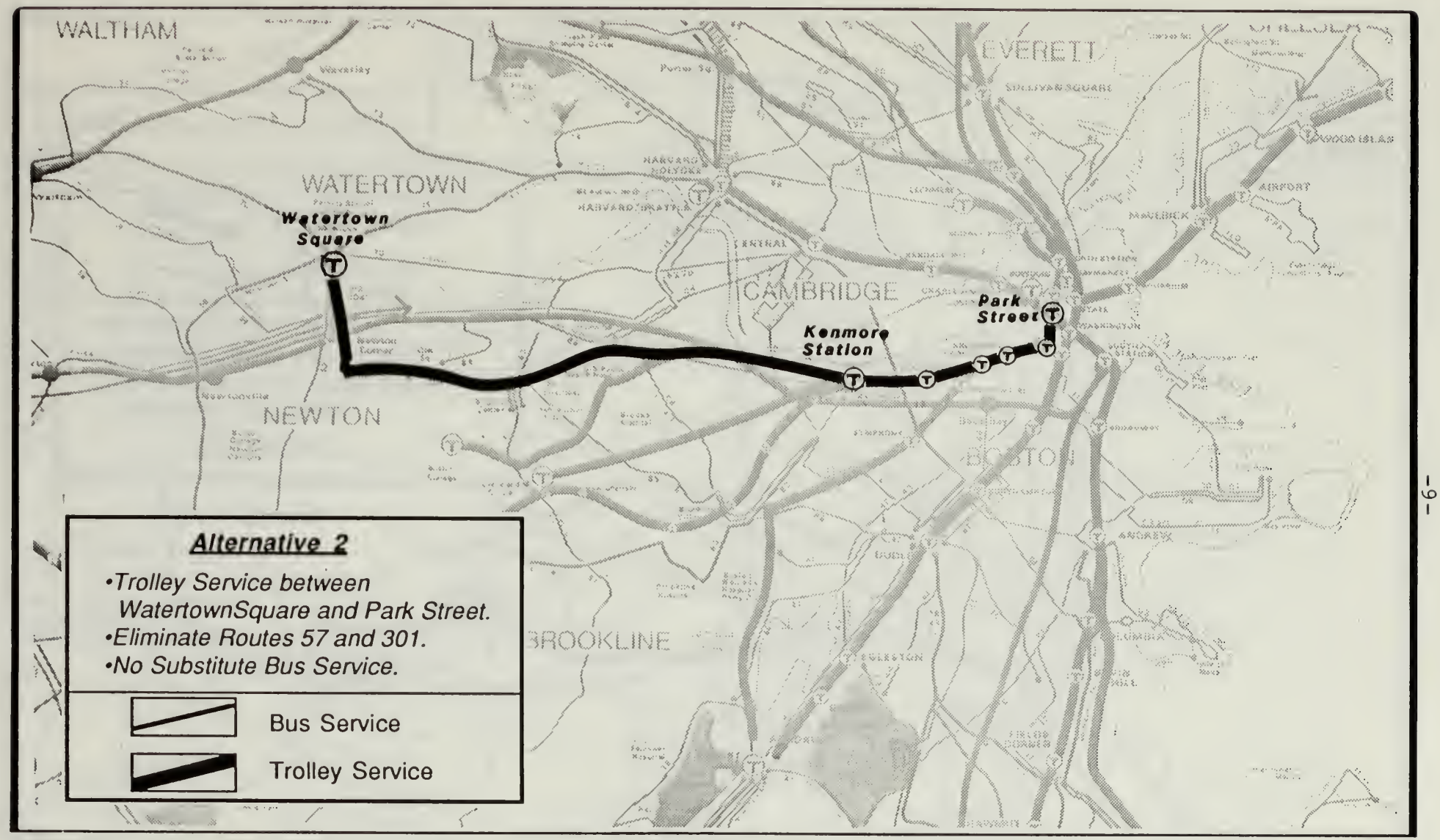
The demand estimate for the base case or do-nothing bus alternative was based on empirical data. Passengers on Route 57 were counted in a Fall 1984 CTPS ridecheck and those using Route 301 were counted in a Spring 1985 pointcheck. These



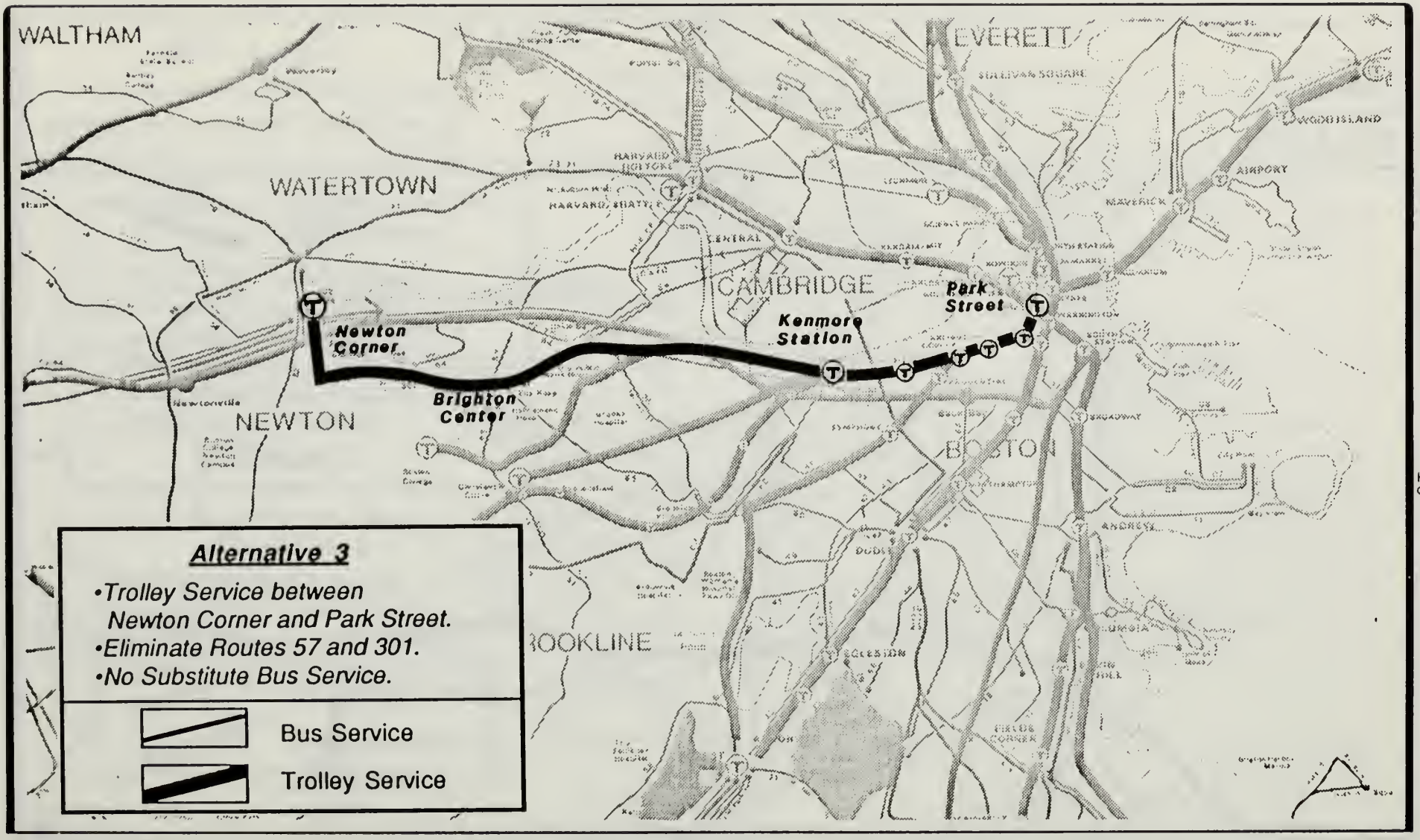
Watertown Trolley Analysis	ALTERNATIVE 0 Existing Bus Service	CTPS
April 1988		FIGURE 2-1



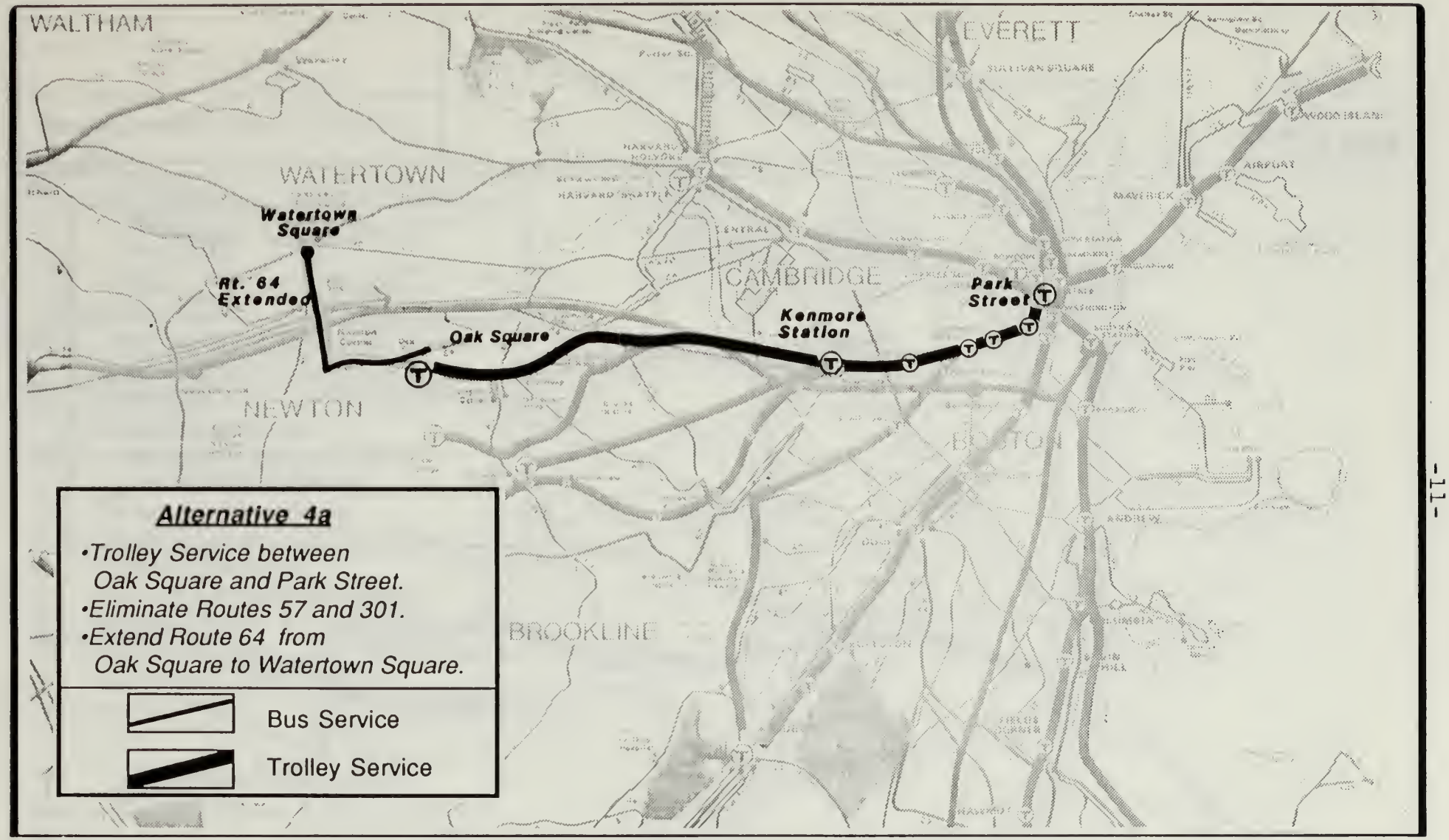
Watertown Trolley Analysis	ALTERNATIVE 1 Existing Bus Service with Free Transfer	CTPS
April 1988		FIGURE 2-2



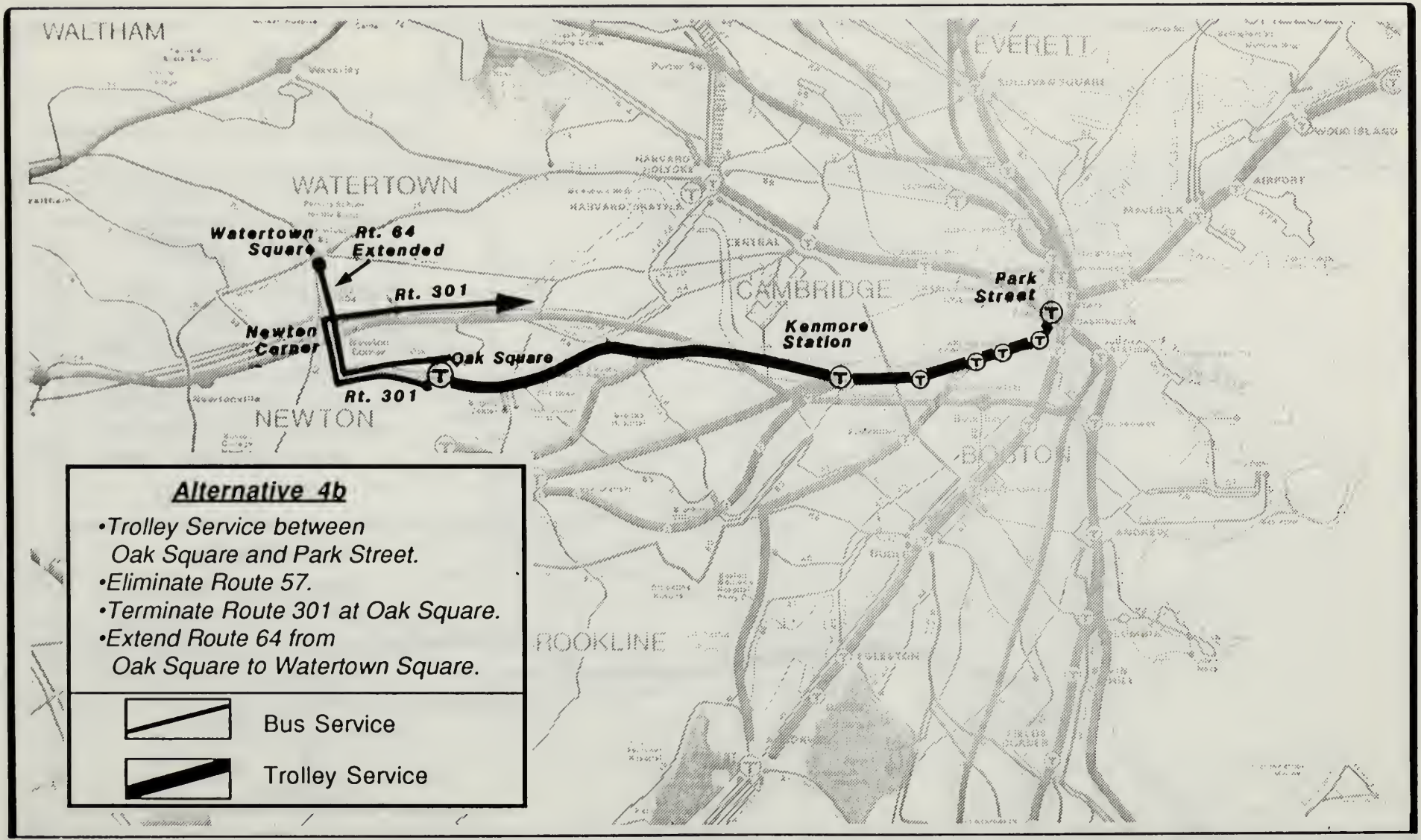
Watertown Trolley Analysis	ALTERNATIVE 2 Trolley Service to Watertown Square	CTPS
April 1988		FIGURE 2-3



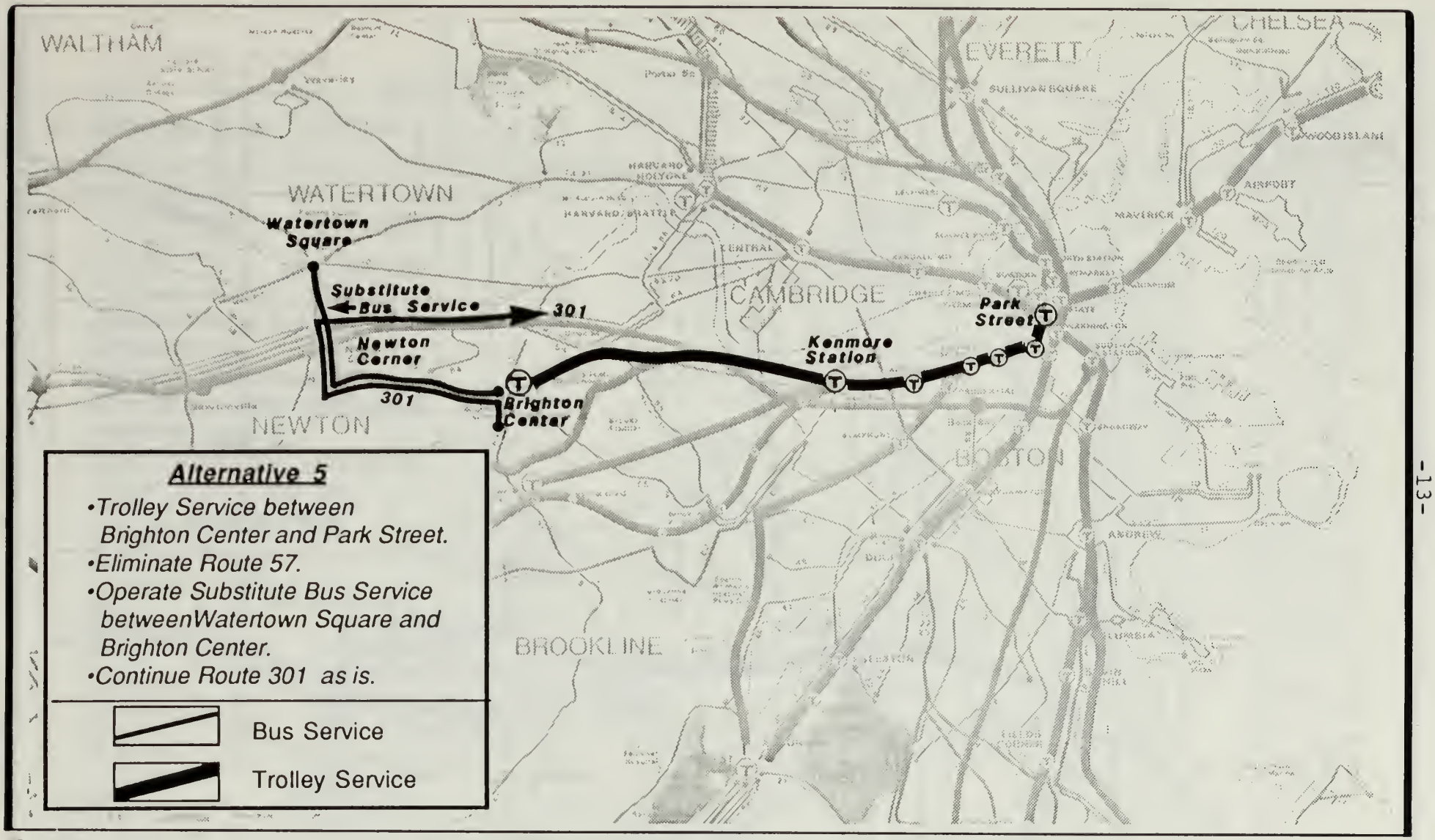
Watertown Trolley Analysis	ALTERNATIVE 3 Trolley Service to Newton Corner	CTPS
April 1988		FIGURE 2-4



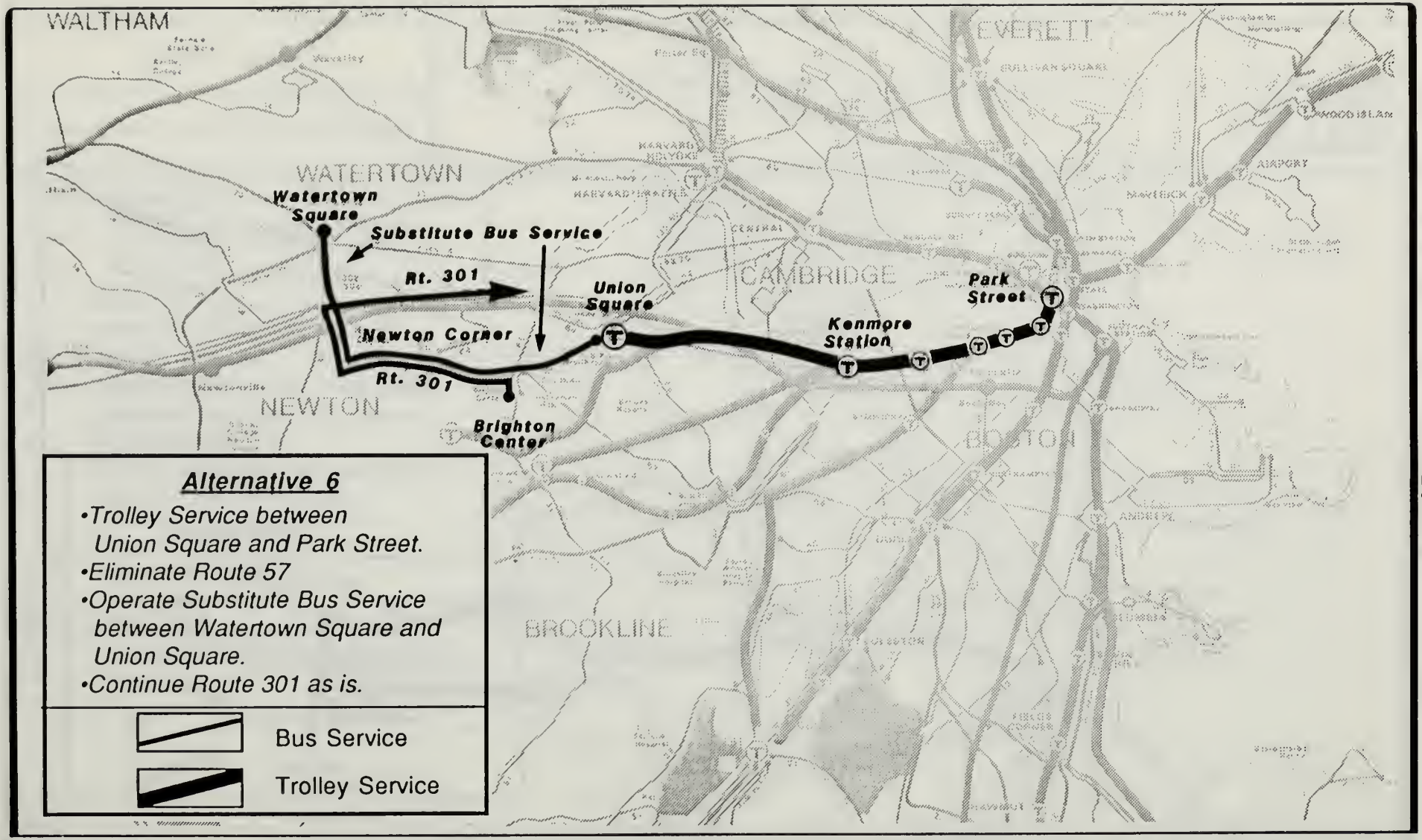
Watertown Trolley Analysis	ALTERNATIVE 4a Trolley Service to Oak Square Without Route 301	CTPS
April 1988		FIGURE 2-5



Watertown Trolley Analysis	ALTERNATIVE 4b Trolley Service to Oak Square With Route 301	CTPS
April 1988		FIGURE 2-6



Watertown Trolley Analysis	ALTERNATIVE 5 Trolley Service to Brighton Center	CTPS
April 1988		FIGURE 2-7



Watertown Trolley Analysis	ALTERNATIVE 6 Trolley Service to Union Square	CTPS
April 1988		FIGURE 2-8

counts were factored to the design year of 1987 based on limited ridechecks conducted more recently. On almost all bus trips counted on both routes, boardings were not capacity-restrained. Thus, the counts provide a good assessment of total bus demand at current fares and levels-of-service.

Demand for the second bus alternative - assuming a free bus/Green Line transfer at Kenmore Station - was derived by factoring the submarket of current Route 57/Green Line transferees upward, using an elasticity factor intended to account for traveller's response to elimination of a transfer cost.

2.2.2 Trolley Alternatives

There were two components to the trolley demand estimation. In the first and major component, demand was estimated for each alternative using an elasticity-based method. Secondly, the reasonableness of the demand estimates was tested using a combination of corridor-level information and ridership data from other Green Line branches, as will be explained.

2.2.2.a Elasticity-based Method

As noted, this method served as the basic demand estimation technique for all trolley alternatives. It entailed defining an initial base demand, and then factoring it by various elasticities to account for the change in service attributes that would occur in substituting trolleys for buses.

The total demand estimate for each of the six basic trolley alternatives includes estimates for three components: the surface portion of the trolley itself; the increase in Central Subway ridership attributable to the A-line; and bus service, including substitute local service and Route 301 service, if applicable. Ridership for the six basic alternatives was estimated first and then the "generic" impact of other design options was calculated afterwards.

Section A.2 of Appendix A contains all of the details underlying the process that is described in more general terms below.

Ridership Estimation Method for the Six Basic Alternatives

The initial base trolley demand for the trolley alternatives was assumed to be composed of those now using Routes 57 and 301, or Route 57 alone, depending upon the alternative. One or both would be terminated upon trolley

service restoration, and since the Route 57 alignment and the local portion of the Route 301 alignment are the same as that of the surface portion of the A-line, this initial base of passengers was "transferred" to the trolley and then adjusted to account for various differences between bus and trolley service.

The first adjustment made to the base market was to calculate how many current travellers would not be served by the alternatives that specify an outer terminal short of Watertown Square. For these alternatives, Route 57 and 301 load profiles were used to determine how many passengers would be beyond one-half mile of the end of the line, and they were then subtracted from the base market.

Concurrently, it was assumed that if Route 301 were retained as is, current riders would continue to use it due to its travel time, seat availability and the fact that, in some trolley alternatives, riding the trolley would entail giving up a one-seat bus ride for a two-seat substitute bus/trolley ride.

The base trolley market was next adjusted to account for the fact that, under current MBTA fare policy, most bus riders, in switching to the trolley, would experience a fare decrease. Ex-Route 57 riders would experience a 23 percent fare decrease, on average, and ex-Route 301 riders would experience a 37 percent decrease. An elasticity factor of -0.35 was applied in conjuction with these percentage decreases and the base market was factored upward accordingly.[1]

Provision of A-line service would eliminate the need to transfer between Route 57 and the Green Line at Kenmore Station for 27 percent of current Route 57 riders. To these travellers, an elasticity of -0.30 was applied to account for the new passengers that would be attracted due to the transfer elimination.

The transfer itself, in addition to the average time actually spent transferring, was assigned a "penalty" of five minutes to account for its inherent negative effect. Including this penalty, a person who currently rides both Route 57 and the Green Line spends 11 to 16 minutes waiting/transferring, depending on the time of day. The elimination of the Kenmore Station transfer would reduce this to three to seven minutes for the average traveller. That is, the current wait time for the Green Line (1-2 minutes),

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[1] All elasticities used in the analysis were taken from, or based on, those presented in Patronage Impacts of Changes in Transit Fares and Services, prepared by Mayworm, et.al., for the U.S. Department of Transportation, September 1980.

the walk time between the bus and the Green Line (2 minutes), and the five minute transfer penalty would be eliminated, leaving just the wait time for the trolley vehicle.

The next step in the demand analysis entailed estimating patronage on substitute bus service, where provided. The base market for this service was assumed to be composed of current bus riders who would live beyond one-half mile of the outer end of the trolley for a particular design scenario. These travellers were initially "loaded" onto the substitute bus service and then factored to account for service attributes different from those they now encounter.

Substitute bus riders would encounter a headway different from that on their current Route 57 or 301 service - longer or shorter depending on the time of day. Furthermore, for those who would be required to pass through a new bus-to-rail transfer point, such as Oak Square or Brighton Center, in order to accomplish their trips, a significant new obstacle to transit travel would be imposed similar to the one eliminated at Kenmore Station for some travellers. In addition, these people who would be forced to make a new transfer would be assessed another fare that they are not now required to pay, assuming that they are currently surface-only bus travellers, or at least a higher transfer fare than they currently pay (75 cents versus 60 cents for an adult cashpayer) if they already transfer to the Green Line. All of these considerations were dealt with through the application of various elasticities.

The substitute bus riders who would transfer to the new A-line were then added to those already assumed to be on it from the previous calculations, and a series of repetitive calculations intended to match trolley headways and demand was undertaken. This process was intended to reflect the real-world consideration that headways are set largely according to ridership, expressed as some maximum allowable load per car, and that ridership is, in turn, sensitive to headways. Initially, the total base trolley market was simply "loaded" onto the A-line assuming A-line headways equal to bus headways. Then, through repetitive calculations, demand and headways were adjusted within two constraints. The first was that the maximum load on a trolley, for scheduling purposes, would not exceed 130. The second was that trolley headways would not be allowed to exceed 15 minutes in any period.

The demand and headway matching was the final step in calculating demand for the surface A-line portion of each basic trolley alternative. The final component of each alternative, increased subway ridership due to the A-line, was calculated using the same elasticity-based approach used for surface A-line and substitute bus service. Assuming that current service on other Green Line branches were held

constant, the addition of A-line cars to the Central Subway would reduce average headways slightly. The percentage reductions, by time of day, were calculated and combined with an elasticity of -0.30 to derive new subway ridership.

In summary, the demand estimate for each of the six basic trolley alternatives is composed of surface trolley riders, substitute bus riders, riders of Route 301 and new subway riders that would be generated by the A-line.

Refer to Section 3.2.1 of Chapter 3 for an alternative-by-alternative presentation of these demand estimates.

Ridership Estimation Method for Additional Design Options

An option appropriate for any of the six basic alternatives would be to operate the line to Government Center instead of Park Street. The additional patronage that would be generated from such an extension was estimated based on the travel patterns of existing users of the Green Line Central Subway. The travel patterns were, in turn, calculated from Green Line boarding and alighting counts performed by CTPS in the Spring of 1985. These data showed that 15-20 percent of inbound Green Line surface travellers ride beyond Park Street.

Other options analyzed "generically" were signal pre-emption, reservations on Cambridge Street and Brighton Avenue, and a subway tunnel under Brighton Center, all of which would be intended to speed trolley service in order to attract more patronage. The subway tunnel would also be intended to avoid trolley impacts on traffic in Brighton Center.

The patronage impacts of these options were calculated by first specifying their precise design and calculating the time savings associated with each. Then, elasticities of from -0.39 to -0.74, depending on the time of day, were applied to the percentage time savings to derive resulting patronage increases.

Section 3.2.3 of Chapter 3 contains a summary of the results of this analysis, and Section A.4 of Appendix A contains the details of the analysis.

2.2.2.b Further Sensitivity Analysis

The surface-to-subway ridership for travellers in the A-line corridor was compared to that on other Green Line branches to see whether the large numbers of travellers "lost" to Route 57 and the Green Line due to there being a transfer at Kenmore could be accounted for when competing

services in the A-line were considered. This analysis was done in order to ensure that all groups of potential riders of A-line service were properly accounted for.

Attachment A3 of Appendix A describes this analysis in more depth, and Section 3.2.4 of Chapter 3 is a summary of the findings.

2.3 COST ESTIMATION METHOD

2.3.1 Method for Estimating Annual Variable Operating Costs

Operating costs for the bus and trolley alternatives were estimated using procedures developed and refined at CTPS. The CTPS cost formulas include variable but not fixed cost components. The most recent CTPS cost formulas were prepared in 1986, using data from calendar year 1984, because that was the latest year for which final costs were then available from all MBTA departments.

The MBTA's cost accounting system requires that every expense incurred be charged to both a so-called Responsibility Area and a Cost Function. The annual total cost charged to each mode is made up of several thousand Responsibility Area-Cost Function combinations. To derive cost formulas, a manageable number of variables was obtained by examining a sub-set of expenses that represent about 90 percent of total expenses for each mode. (The remaining 10 percent consist of a large number of items that individually account for very small percentages of total cost.)

For the 90 percent of costs included in the analysis, an item-by-item determination was made as to whether each was fixed or variable. The former were excluded from further analysis and variable costs were disaggregated according to which unit of service - vehicle-miles and vehicle-hours, for example - each was most closely related.

Expenses for certain functions, particularly those in maintenance categories, may fluctuate greatly from year-to-year, so results from a single year could significantly overstate or understate typical costs. For such functions, cost trends over several years were examined and adjustments made as necessary. Whenever possible, large one-time expenses, such as vehicle retro-fitting programs, were identified and excluded from the formulas.

More detailed information about this cost method can be found in Appendix B, and the results of the analysis are presented in Section 3.3.1 of Chapter 3.

2.3.1.a Bus Operating Cost Model

The formula derived for bus operating costs consists of four variables as follows: bus-hours, bus-miles, total buses required for a route, including spares, and the weekday peak vehicle requirement.

Bus-hour costs include wage and fringe-benefit costs. Bus-mile costs include fuel, mile-related maintenance costs and liability costs. Annual vehicle costs, captured in the total bus requirement variable, consist of maintenance costs, such as inspection and cleaning, that are incurred more on the basis of time than mileage. Peak vehicle costs, captured in the variable for weekday peak vehicle requirements, include such costs as on-line superintendence and dispatching. These differ from the annual costs in that they are distributed over weekday maximum vehicle requirements, exclusive of spares.

The bus cost formula derived, then, is as follows:

Annual Operating Cost = \$19.30(Annual Bus-Hours)
+ \$1.32(Annual Bus-Miles)
+ \$4,100/year(Total Bus Requirements)
+ \$11,000/year(Peak Weekday Veh. Req.)

A factor of ten percent was added to account for the variable costs not specifically represented in the formula.

Refer to Section B.2 of Appendix B for more information.

2.3.1.b Trolley Operating Cost Model

The formula derived for trolley costs consists of car-hours, car-miles, total vehicles required for the route and peak vehicle requirements. These variables are analogous to those used for buses. In this case, they were disaggregated by surface and subway. Additionally, costs attributable to A-line service for maintaining and operating fixed facilities and for on-line supervision were accounted for.

As with buses, car-hour costs include wages and fringe benefits. Car-mile costs include those for electric power, mileage-based vehicle maintenance and liability. Annual vehicle costs, captured in the total vehicle variable, consist of time-based components of vehicle maintenance. Weekday peak vehicle costs, captured in the peak vehicle variable, consist of those for dispatching and for removing and transporting fare revenue from vehicles to a counting area.

The trolley cost formula derived, then, is as follows:

Annual Operating Cost = $20.59(Annual Surface Car-Hours)
+ $19.20(Annual Subway Car-Hours)
+ $1.67(Annual Subway Car-Miles)
+ $2.72(Annual Surface Car-Miles)
+ $62,000/year(Total Assigned Vehicles)
+ $4,100/year(Peak Scheduled Vehicles)
+ $61,000/year(Exclus. A-line Rte-Mles)
+ $159,000/year(# Inspector Locations)

A factor of ten percent was added here, too, to account for the variable costs not specifically covered in the formula.

Refer to Section B.3 of Appendix B for more information.

2.3.2 Method for Estimating Capital Costs

In computing capital costs for the bus and trolley alternatives, two steps were taken. The first was to derive the initial costs that would be associated with each alternative. Then, using assumptions about the life spans of capital facilities, an assumed project horizon, and various discount rates, the present value of all capital costs, initial and future, was calculated. Using the same set of assumptions, capital costs were also calculated on an annualized basis, so that they could be compared to annual operating costs and revenues. Throughout the analysis, only non-federal costs were considered, and costs cited in this report are non-federal unless otherwise noted, by, for example, the use of the word "total".

The first assumption used for calculating present values and annualized costs for all alternatives was the project horizon. This was specified as 25 years.

The second such assumption common to all alternatives was the interest rate used for discounting costs incurred in future years and for annualizing costs over the project horizon. Since much latitude exists in choosing a reasonable discount rate, various rates were used to see whether bottom-line findings turned on which rate is used. The mid-range rate used was 8.4 percent; 6.9 percent and 9.9 percent were used as the upper and lower-bound rates, respectively. In order to present trolley capital costs as favorably as possible, the results summarized in this report are based on the 6.9 percent rate.

A third assumption used in calculating present value and annualized costs for all alternatives was that non-inflated costs would be used for future year costs. This was deemed appropriate so long as the discount rate used is exclusive of inflation. Strictly speaking, the discount rates used are not exclusive of inflation, but the 6.9 percent rate does

reflect present day conditions in which inflation is low. Moreover, the various interest rates used ensures that results will not be potentially misleading due to the use of an improper interest rate.

All capital costs, initial and future, for all alternatives, were assumed to be split 60/40, federal/non-federal. This is based on the fact that approximately half of the MBTA vehicles purchased recently were purchased with no federal money and half were purchased using federal funds for 80 percent of the cost.

See Section 3.3.2 of Chapter 3 for a summary of capital costs among alternatives, and Appendix C for a more complete recounting of the analysis method.

2.3.2.a Bus Alternatives

The only capital cost associated with these two alternatives would be for the buses themselves. The current replacement cost of all 28 buses (including spares at a spare ratio of 1.15) used on Routes 57 and 301 was attributed to these alternatives. Replacement cost was used notwithstanding that, in reality, the buses being used currently would be replaced gradually over several years. Rather, this was done in order to be consistent with the costing of the trolley alternatives, which assume, in effect, that the entire trolley fleet would have to be purchased now.

The analysis assumed a total (federal plus non-federal) unit bus cost of $141,708, based on the most recent price paid by the MBTA for RTS II buses. In arriving at a present value cost for the bus alternatives, a vehicle life span of 12 years was assumed, based on the MBTA's objective of replacing buses after twelve years of service.

The present value of this alternative, then, includes the initial replacement cost of all buses, the discounted cost of having to replace all of them again in 12 years, and a one year allocation of the cost required to replace them a third time in the second to the final year of the project horizon. This costing assumed no change in the current level of service.

Refer to Appendix C, Section C.4 for more information.

2.3.2.b Trolley Alternatives

Capital costs for the trolley alternatives can be divided into three major categories: vehicle acquisition, right of way and Yard improvement, and optional priority schemes for some of the alternatives.

Vehicle acquisition costs would include those for trolley vehicles, and most alternatives would also include some costs for replacement buses. The total unit cost of trolley vehicles was assumed to be $1,060,000, based on the most recent price paid by the MBTA for trolley Type 7 vehicles. The total unit cost of buses for replacement service was assumed to be $141,708, as in the bus alternatives.

The current A-line right of way west of Packard's Corner would need to be improved for revenue operations. The MBTA estimated that if the line were operated all the way to Watertown Yard, 35 percent of the line would need to be totally reconstructed, including removal and replacement of all asphalt, rail, ties and ballast; and rail joints on approximately 65 percent of the line would need to be replaced. Additional funds would need to be spent upgrading the overhead wire system (including pole replacement), in order to accommodate pantograph operation.

Costs would be incurred in reconstructing Watertown Yard, if service were operated out that far. Shorter versions of the line would require construction of turn around facilities appropriate to each.

All right of way, Yard and turn around cost estimates were obtained from the MBTA.[2] In addition, CTPS performed an inspection of the entire right of way west of Packard's Corner in order to derive an independant estimate of upgrading needs.

If any trolley priority schemes were employed, additional capital costs would be incurred. The effect on demand of three such schemes was analyzed: a subway tunnel, reservations, and signal pre-empton. Total subway costs of $17.2 million were estimated based on those for a similar tunnel in Pittsburgh. Reservations were estimated to cost a total of $65.74 per linear foot and signal pre-emption, $10,000 per intersection and $1,500 per vehicle, based on a variety of sources. Appendix C, Section C.6, contains all of the information used in this costing.

In arriving at total present value capital costs and annualized capital costs for the trolley alternatives, the trolley vehicles were assumed to have a 25 year life span. Because the project horizon is also 25 years, no future trolley replacement cost would be incurred. Replacement buses, with a 12 year life span would, however, have to be replaced in future years, and these costs were accounted for as they were in the two bus alternatives.

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[2] MBTA Memorandum, "Watertown Line," Edward J. Rowe, Acting Chief Engineer, February 19, 1987.

Costs for maintaining tracks and for replacing wires and poles would be incurred again during the project horizon, given the life spans of these facilities, but these costs were included in annual operating costs, rather than as future capital costs.

2.4 REVENUE ESTIMATION METHOD

The revenue estimate for each alternative is a function of its patronage and fare mix. The patronage was estimated previously and basic fare mixes used were obtained directly from surveys. Revenue for each alternative was computed on an annual basis. Appendix D recounts in greater depth the method described below.

2.4.1 Bus Alternatives

The bus fare mixes, including pass mixes, were obtained from on-board survey questionnaires administered on Routes 57 and 301 by CTPS in conjunction with recent bus corridor studies. Using this information along with the respective fare structures of the routes, the average one-way fares paid by bus patrons were computed (42 cents for Route 57 and 83 cents for Route 301). In the case of pass-users, monthly pass costs were divided by the number of assumed pass uses per month (47 on surface vehicles) to derive average fares per pass use. All pass use assumptions used in the analysis were based on information from recent MBTA fare-mix studies done by CTPS.

The revenue for the bus alternatives is primarily composed of revenue obtained on the buses, but it also includes revenue obtained on the Green Line by Route 57 transferees. Section 3.4.1 of Chapter 3 summarizes the revenue estimates for these bus alternatives.

2.4.2 Trolley Alternatives

Two major assumptions underlie the estimation of revenue for trolley alternatives. First is that the A-line would be priced consistent with other Green Line branches (surface fares would be $0.75 inbound and free outbound and subway fares would be $0.60). Second, since the major share of A-line patrons would be former Route 57 and 301 riders, it was assumed that the A-line fare mix would be the same or similar to the bus fare mixes.

Revenue was estimated by first disaggregating travellers into sub-markets. There are three sub-markets of travellers contained in the A-line surface ridership estimates, and each would have an average one-way fare different from the others. Some travellers would be ex-Route 57 riders travelling solely

on the surface portion of the A-line. Others would be ex-Route 57 riders travelling into the subway on the A-line. Still others would be ex-Route 301 riders travelling into the subway on the A-line. Newly induced travellers who would not have come from the two buses in question were assumed to have the same fare mixes as the ex-bus riders. The fare mix specific to each sub-market, along with the set of fares encountered by each was used to compute the average one-way fare unique to each group.

The market of new Central Subway riders induced by the presence of the A-line would have a unique average fare. Due to a lack of Central Subway fare mix information, this fare was estimated by applying the rapid transit system fare mix to the Green Line fare structure.

Substitute bus riders would be composed of four separate sub-markets: ex-Route 57 riders using the substitute bus only, using the A-line on the surface, and using the A-line into the subway; and ex-Route 301 riders using the A-line into the subway. Again, each would be faced with a specific set of total trip fares and it was assumed that each would exhibit the fare mix of the bus from which they came.

Finally, for those alternatives in which Route 301 is retained, the present average one-way fare was used.

As in the bus alternatives, monthly pass costs were divided by assumed monthly pass uses to derive average fares for pass-users. Assumed pass-mixes and monthly pass uses varied by travel sub-market. Refer to Section D.4.2.c in Appendix D for more specific information.

The total estimated annual revenue for each trolley alternative, then, consists of that obtained from A-line surface travellers, exclusive of transferees from substitute buses; subway-only travellers; substitute bus travellers, where applicable, including those who transfer to the A-line; and Route 301 travellers, where applicable. These estimates are presented in Chapter 3, Section 3.4.1.

2.5 GREEN LINE IMPACT - ISSUES EXAMINED

Three issues were examined with regard to how the A-line would impact existing services: the location of the inner terminal, the line's interaction with the B-line on the surface and its interaction with other lines in the Central Subway. Refer to Appendix E for details on method and findings, and to Chapter 3, Section 3.5 for a summary of findings.

2.5.1 Inner Terminal

It is assumed in the basic alternatives that the A-line would terminate at Park Street. This was based on the considerations that the line has to extend at least that far past Kenmore in order to encounter turn around facilities, but need not go farther, given that 80-85 percent of inbound surface passengers alight at or before Park Street. The cars on the line, as with others, would not be able to lay over at Park Street due to a lack of storage capacity there. Rather, layover time would be loaded onto the outer end of the line. If, in any particular alternative, a layover facility could not be provided at the line's outer end, the inner terminal would have to be extended to North Station or Lechmere where sufficient layover capacity exists.

It was assumed for costing and demand estimation purposes that layovers could, indeed, be accomodated at the outer end of each alternative alignment and that, therefore, Park Street would be an appropriate inner terminal.

2.5.2 Interaction With B-line

Two issues were addressed here, one logistical and one of a service nature. The A-line would share its surface right of way with the B-line from the Blandford Street portal west to Packard's Corner. At issue is whether the amount of service assumed in the trolley alternatives could be added to existing B-line service without causing any problems. Such considerations as minimum train spacing, power consumption on the line segment, and experience when the line used to operate were examined in evaluating this issue.

Secondly, the issue of whether B-line service could be reduced upon A-line restoration, given that some travellers would switch from one to the other, was examined. Boarding and alighting patterns on the two lines, one actual and the other estimated, were used to derive the net number of people who could actually be expected to switch from the B to the A-line and the implications for B-line levels of service.

2.5.3 Interaction With Other Lines in the Central Subway

The A-line would share the Central Subway from Kenmore Station east with the B, C and D-lines, and from Copley Junction east with the E-line, as well. The signal system, minimum train spacing requirements, power consumption and previous operating experience all were used in evaluating whether the introduction of the A-line would cause any problems in Central Subway operations.

2.6 TRAFFIC IMPACT - ESTIMATION METHOD AND ISSUES

Three issues were examined with regard to the traffic impacts associated with substituting trolleys for buses. The first is the degree to which traffic in Allston and Brighton would be affected. A sub issue examined within this was the impact that trolley priority schemes, in addition to restored trolley service itself, would have on traffic. The second issue is the degree to which traffic in Boston's CBD would benefit from eliminating Route 301 and finally, the traffic issues that would arise from operating trolleys through Newton Corner were examined. See Appendix F, Traffic Impact Analysis, for detailed information, and Section 3.6 of Chapter 3 for a summary of findings.

2.6.1 Allston and Brighton

The approach taken in this analysis was to model the present performance of one signalized intersection with its associated bus traffic and then to model its performance assuming trolley substitution for buses. This was done because trolleys would exert their greatest influence on traffic at signalized intersections, of which there are eleven on the Allston/Brighton portion of the alignment. Further, since the analysis was done for the PM peak hour, the results show what something close to the worst impact resulting from trolleys would be.

The effect that buses and trolleys have on intersection delay was calculated using their passenger car equivalents in the vehicle stream. That is, each vehicle, given certain of its inherent characteristics, and given prevailing traffic, geometric and signal characteristics, has an impact on traffic equivalent to a certain number of passenger cars. This passenger car equivalency varies by location. Once these passenger car equivalents were calculated at the intersection of interest, the net increase in them, resulting from trolley substitution (A trolley would have a greater passenger car equivalent than a bus at this location. See Section F.3.1.a of Appendix F for a full explanation.) was added to the existing traffic volumes and the changes in various measures of the intersection's performance were calculated. These measures are average stopped delay per vehicle, the volume to capacity ratio and an associated level-of-service value ranging from A to F.

The impacts that a subway tunnel, reservations and signal pre-emption would have on vehicular traffic were also examined in this section. The analysis was quite generalized due to a lack of detailed information, and qualitative issues such as logistics were dealt with. Field observations of

signal timings, track location and general alignment characteristics served as input to the examination.

2.6.2 Boston CBD Traffic

The approach used here was to obtain recent traffic volume counts for the streets traversed by Route 301 and to calculate Route 301 bus traffic as a percentage both of these volumes and of total express bus volumes alone. (With four other routes in addition to 301 operating along the same alignment, total bus volumes during peak periods are fairly high.) Additionally, field observations of the performance of the intersections through which Route 301 buses travel were made to see whether eliminating the 301 buses might conceivably cause poorly performing intersections to improve.

2.6.3 Newton Corner

With limited time and data available for the analysis, Newton Corner could not be modelled as was Brighton Center. However, the traffic issues in Newton Corner can largely be framed in qualitative terms.

The quantitative analysis involved obtaining recent PM peak traffic volume counts of the rotary system, assuming a passenger car equivalency difference between buses and trolleys, which was based on the Brighton Center work, and adding this difference to the traffic volumes to obtain a rough estimate of the percentage increase in equivalent traffic volume that substituting trolleys for buses would imply.

Several qualitative issues were examined. Chief among them was logistics. Southbound trolleys, if operated over the present right of way, would operate counter to vehicular traffic on the easternmost Centre/Washington Street bridge. Measures designed to provide southbound trolleys the right of way there would likely cause traffic problems. In particular, westbound traffic exiting the Mass Pike in the PM peak-period would probably back up onto the Pike even more than it does now and this is already a severe safety hazard.

The options of running the trolley right of way over or under this segment would be very expensive. In the latter case, a subway tunnel would have to be dug under the Mass Pike and the parallel railroad tracks. For this reason, it was assumed for costing purposes that the tracks at Newton Corner would loop around the rotary so that trolleys would always be travelling in the same direction as vehicular traffic.

3 FINDINGS

3.1 OVERALL

Table 3-1 and Figure 3-1 summarize the demand, cost and revenue estimates derived for all alternatives. The major findings represented by this information are as follows:

- The base case bus alternative would be the least costly on the basis of net cost per passenger (the sum of annualized capital costs and variable operating costs, minus annual revenue, divided by annual passenger trips).

- The base case bus alternative would be the least costly on the basis of net present value.

- The base case bus alternative would cover a greater portion of operating expenses than other alternatives.

- Among trolley alternatives, #4a, (Oak Square to Park Street without Route 301), would be the most financially efficient on all measures and #5, (Brighton Center to Park Street) would be the least so.

Table 3-2 presents additional summary information. The major findings represented in it are as follows:

- Capital costs for trolley alternatives would exceed those of the base case bus alternative by 35% to 390%.

- Two trolley alternatives - #2 (Watertown) and #3 (Newton Corner) - would result in 1,090 and 370 new daily users over the base case; other trolley alternatives would result in losses of from 600 to 1260.

- Trolley alternatives would increase current operating deficits by $554,000 to $1,740,000 annually.

Other analyses performed found that:

- Substituting trolleys for buses would have a measurable negative effect on vehicular traffic, but removing Route 301 buses from downtown Boston would have no measurable beneficial impact.

Discount Rate 6.90%	ALT 0 Bus Only Base Case	ALT 1 Bus Only free Transfer	ALT 2 Trolley Watertown	ALT 3 Trolley Newton Corner	ALT 4a Trolley Oak Sq.	ALT 4b Trolley Oak Sq.+301	ALT 5 Trolley Brighton Ctr.	ALT 6 Trolley Union Square
Weekday Linked Trips - Both Directions	12090	12560	14380	12880	10830	10700	10100	9450
Annual Total Demand - Linked Trips	3421000	3559000	4045000	3626000	3032000	3028000	2855000	2671000
Annual Variable Operating Cost	$3,083,351	$3,083,351	$3,900,433	$3,679,226	$3,090,112	$3,523,877	$4,384,814	$4,165,545
Annualized Non-Federal Capital Cost	$197,391	$197,391	$885,967	$728,831	$470,142	$482,788	$336,313	$269,377
Total Annual Gross Cost	$3,280,742	$3,280,742	$4,786,400	$4,408,057	$3,560,254	$4,006,665	$4,721,127	$4,434,922
Annual Passenger Revenue	$2,066,970	$1,767,685	$1,869,884	$1,684,413	$1,520,063	$1,614,922	$1,628,750	$1,590,184
Total Annual Net Cost	$1,213,772	$1,513,057	$2,916,516	$2,723,644	$2,040,191	$2,391,743	$3,092,377	$2,844,738
Gross Cost per Passenger Trip	**$0.96**	**$0.92**	**$1.18**	**$1.22**	**$1.17**	**$1.32**	**$1.65**	**$1.66**
Net Cost per Passenger Trip	**$0.35**	**$0.43**	**$0.72**	**$0.75**	**$0.67**	**$0.79**	**$1.08**	**$1.07**
Revenue to Operating Cost	**67%**	**57%**	**48%**	**46%**	**49%**	**46%**	**37%**	**38%**
Net Present Value (costs-revenue)	**$14,305,513**	**$17,832,884**	**$34,374,042**	**$32,100,855**	**$24,045,677**	**$28,189,072**	**$36,446,743**	**$33,528,066**

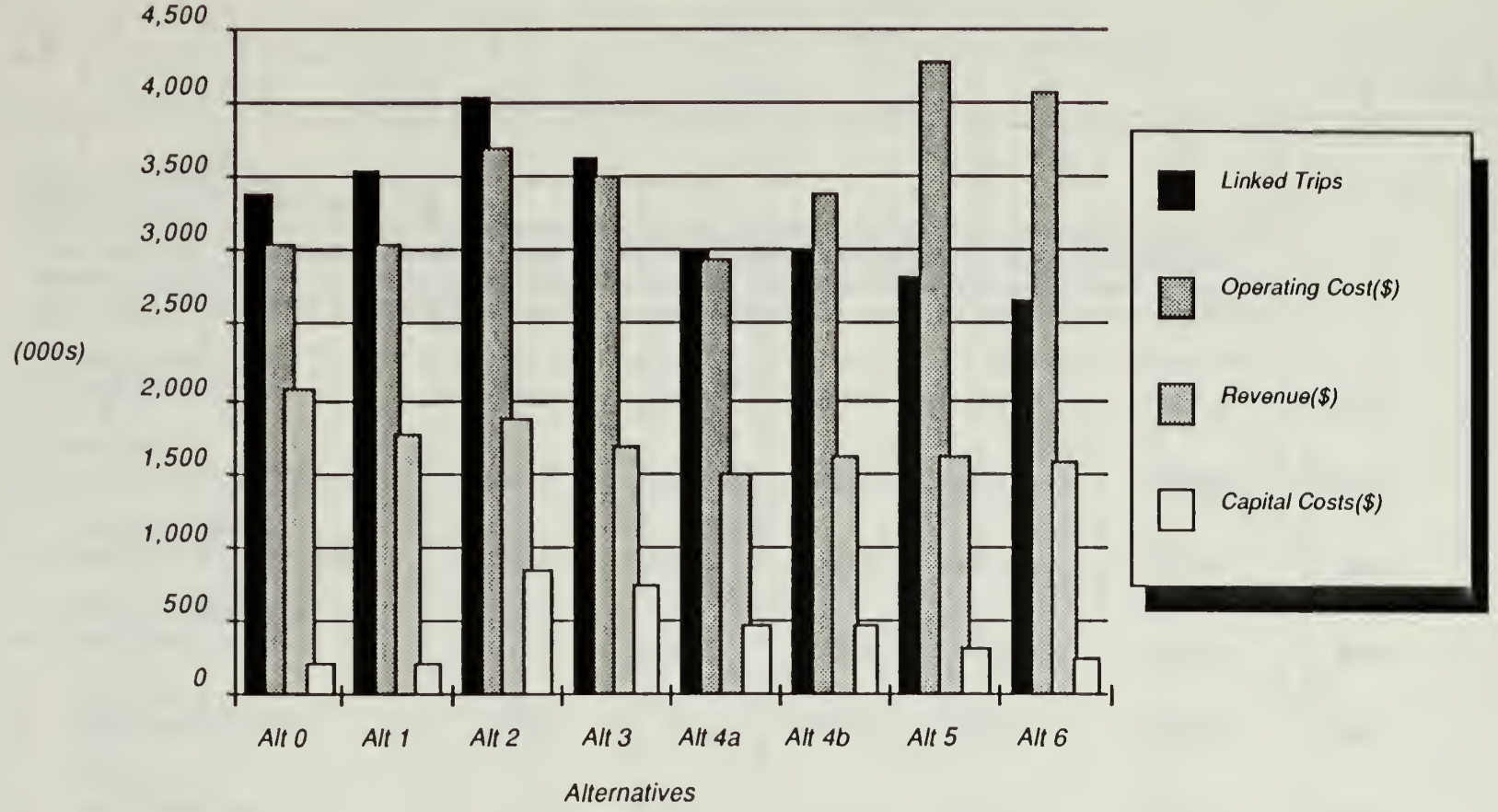
Watertown Trolley Analysis

April 1988

SUMMARY STATISTICS
All Alternatives

CTPS

TABLE
3-1



Watertown Trolley Analysis	COMPARISON OF ANNUAL RIDERSHIP, OPERATING COSTS, REVENUE, AND CAPITAL COSTS	CTPS
April 1988		FIGURE 3-1

ALTERNATIVE	Total Daily Users	Daily New Users	Total Daily Boardings*	Total Daily Linked Trips*	Capital Costs (000s) **	Change in Operating Deficit (000s/yr)
0. Existing Bus (Base Case)	5,760	0	12,090	12,090	$2,326	$0
1. Existing Bus w/Free Transfer	5,980	220	12,560	12,560	$2,326	$299
2. Trolley Watertown Sq - Park Street	6,850	1,090	14,380	14,380	$10,442	$1014
3. Trolley Newton Corner - Park Street	6,130	370	12,880	12,880	$8,590	$979
4a. Trolley Oak Sq - Park Street w/o Rt 301	5,160	-600	11,910	10,830	$5,541	$554
4b. Trolley Oak Sq - Park Street w/Rt 301 to Oak Sq	5,090	-670	11,720	10,700	$5,690	$893
5. Trolley Brighton Center - Park Street	4,810	-950	11,550	10,100	$3,964	$1,740
6. Trolley Union Square - Park Street	4,500	-1,260	11,360	9,450	$3,175	$1,560

*Total Daily Boardings refer to unlinked trips - the total number of boardings on all components of each alternative, whereas linked trips are complete trips from origin to destination, irrespective of the number of modes used or transfers made. The difference between the two figures can be seen in the following example: One linked trip from Watertown Square to downtown Boston on Route 57 and the Green Line involves two unlinked trips: one on Route 57 and one on the Green Line.

**Non Federal share only.

Watertown Trolley Analysis	SELECTED SUMMARY STATISTICS All Alternatives	CTPS
April 1988		TABLE 3-2

• Under present and proposed levels of service, there is sufficient capacity for the A-line to operate on the Commonwealth Avenue reservation and in the Central Subway.

3.2 DEMAND

The major findings from the demand analysis are listed below. Unless otherwise noted, figures are in terms of linked passenger trips per weekday.[3]

• Total demand for the base case bus alternative was estimated to be 12,090 passenger trips per weekday.

• Alternative 2, with a free transfer at Kenmore Station for Route 57 riders, would generate an additional 4% or 470 passenger trips over the base case.

• Total demand for trolley alternatives would range from a high of 14,380 to a low of 9,450 passenger trips per weekday. Demand would decrease as the A-line became shorter because more and more people would be forced to transfer to complete their trips.

• Two trolley alternatives, Watertown and Newton Corner, would generate more passenger trips than the base case bus alternative - 2,290 or 19% more for the Watertown and 790 or 7% more for the Newton Corner alternative.

• The other four trolley alternatives would generate fewer passenger trips than the base case: 10% to 22% or 1260 to 2,640 fewer, depending on the alternative.

• Boardings on the surface A-line would represent the largest share (68% to 91%) of total boardings for Alternatives 2 through 4b.[4] In Alternatives 5 and 6, in which the A-line would be much shorter, A-line boardings would represent only 51% and 36% of the totals, respectively.[5]

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[3] A linked passenger trip is one complete one-way trip from initial origin to ultimate destination, irrespective of the number of mode transfers that may be made.

[4] The terms "boardings" and "unlinked passenger trips" are synonymous. Whenever a traveller enters a transit vehicle, it is counted as a boarding. A linked passenger trip is composed of one or more boardings.

[5] Surface ridership is composed of those trips that have at least one end on the surface portion of the line. Subway ridership is defined as that which occurs entirely in the subway.

• Projected increases in subway trips vary little by alternative: from 1,000 to 1,250. These would represent a uniform 9% of total boardings for each alternative.

• Boardings on substitute bus service would increase as its route mileage increased: from 1,220 in Alternative 4a to 4,030 in Alternative 6, representing from 10% to 35% of total boardings per alternative.

• Route 301, in the three alternatives that include it, was assumed to retain its present ridership of 2,220 in the two alternatives where it is left as is and this would represent 20% of the boardings of these alternatives. In Alternative 4b, in which the route is assumed shortened, its ridership would drop to 1,490 or 13% of the total boardings for the alternative.

• In terms of daily users, Alternatives 2 and 3 would result in gains of 1,090 and 370 over the base case, respectively. The other four trolley alternatives would result in losses of from 600 to 1,260 compared to the base case.

The findings summarized below are also treated in depth in Appendix A.

3.2.1 Demand for Bus Alternatives

Alternative 0 (Base Case): Riders of the existing buses were counted in recent CTPS ridechecks. Passenger trips per weekday total 12,090 for the alternative. Of these, 9,870 are on Route 57 and 2,220 are on Route 301.

Alternative 1 (Free Kenmore Transfer): It was found that 27 percent of Route 57 passengers transfer to the Green Line at Kenmore Station. Provision of a free transfer for these people would decrease their round trip fares by about 50 percent. Using an elasticity of -0.35, an estimated increase of 17.5 percent or 470 such transfer trips per weekday results. This would result in a 3.9 percent increase in passenger trips over the base case.

3.2.2 Demand for Trolley Alternatives

Alternative 2 (Watertown - Park): With this alternative, Routes 57 and 301 would be replaced with trolley service over the entire A-line alignment. Trolleys would operate on 7, 10 and 14-15 minute headways in the AM peak, PM peak and base periods, respectively.

The ridership for this alternative is the highest. It would be 14,380 or 19 percent above the base case. It would be composed of 13,120 surface trips on the A-line and 1,250 induced subway trips.

The lower average fare on the A-line would attract 1,090 passenger trips. The elimination of the transfer would attract 560, but the longer headways of the A-line would offset these gains by 620.

Alternative 3 (Newton Corner - Park): In this alternative, Routes 57 and 301 would be replaced by trolley service operating as far as Newton Corner. Consequently, 1,090 current Route 57 riders north of Newton Corner would be left without service. Trolleys would operate on 8, 11 and 13-15 minute headways in the AM peak, PM peak and base periods, respectively.

Total demand for the alternative would be 12,880 passenger trips per weekday or 7 percent greater than base case ridership. Of that, 11,700 would be surface A-line ridership and 1,180 would be induced subway ridership. Offsetting the ridership loss from north of Newton Corner would be an increase of 1,000 due to the lower A-line average fare and 500 due to the elimination of the transfer. But then, 810 passenger trips would be lost due to A-line headways being longer than bus headways.

Alternative 4a (Oak Square - Park, No 301): With this alternative, trolley service would be operated as far west as Oak Square on 10 to 14 minute headways. Both Routes 57 and 301 would be eliminated, but Route 64 would be extended from Oak Square to Watertown Square to provide substitute local service.

Total demand for the alternative would be 10,830 passenger trips or 10 percent lower than the base case. Boardings would total 11,910. Of these, 9,570 would be on the A-line surface, 1,120 would be induced subway trips and 1,220 would be on the substitute bus service. It was projected that 1,080 of the latter would transfer to the A-line at Oak Square.

Most of the decline in demand for this alternative would be attributable to the low level of service specified for substitute buses and the imposition of a transfer, at Oak Square, on many riders who currently do not have to transfer anywhere on their trips. Of the 3,060 boardings on Route 57 that have a trip end beyond walking distance west of Oak Square, 830, at most involve a transfer to the Green Line; with this alternative, 2,750 would be required to transfer. Similarly, the 360 boardings that would be shifted from Route 301 to substitute bus service would represent travellers who would be compelled to transfer to the Green Line.

Alternative 4b (Oak Square - Park, Shortened 301): In this alternative, trolley service would operate at 13 to 15 minute

headways throughout the day. Route 301 service between Oak Square and downtown Boston would be retained at current service levels, but service between Oak Square and Brighton Center would be terminated. Route 57 service would also be terminated, with substitute bus service provided between Oak Square and Watertown Square through extension of Route 64, as in Alternative 4a.

Surface trolley and substitute bus boardings would be lower than in Alternative 4a, at 8,020 and 1,170 trips per weekday, respectively, and 1,020 would transfer between the two services. However, when Route 301 boardings (1,490) are considered, total boardings at 10,680 would be essentially the same as in Alternative 4a.

As with Alternative 4a, a significant amount of ridership would be lost due to the imposition of a transfer at Oak Square. In this case, the imposition of the transfer would result in a loss of 1,730 existing trips, while the lower substitute bus headways would result in a loss of 160 trips between Watertown Square and Oak Square. These losses would be only partially offset by an increase of 870 trips between Oak Square and Park Street due to the re-introduction of A-line service.

Alternative 5 (Brighton Center - Park): In Alternative 5, trolleys would operate on 13 to 15 minute headways throughout the day between Brighton Center and Park Street. Route 301 would be retained, and Route 57 would also continue to operate, but only between Watertown Square and Brighton Center.

With this configuration, total linked passenger trips would be 10,100 and total boardings would be 11,550 per weekday. Surface boardings on the A-line were estimated at 5,910 and the increase in subway ridership at 1,020 trips per day. Boardings on the shortened Route 57 were estimated at 2,400, of which 1450 would involve transfers with the A-line. Boardings on Route 301 were estimated to remain at 2,220 per day.

Most of the surface ridership loss would be due to the imposition of a transfer at Brighton Center, for the same reasons as in Alternatives 4a and 4b. In this case, the imposition of the transfer and the increased wait time due to longer Green Line headways at Brighton Center would result in a loss of 2,420 existing trips.

Alternative 6 (Union Square - Park): For this alternative, A-line service between Union Square and Park Street would operate on 12 to 15 minute headways throughout the day. Route 301 would be retained, but Route 57 would be shortened to operate only between Watertown Square and Union Square.

Both Routes 57 and 301 would operate at their current service levels.

With this configuration, total linked passenger trips would be 9,450 or 22 percent less than the base case. Boardings on the surface A-line between Kenmore and Union Square would be 4,070 per day and the subway increase would be 1,040 per day. Route 301 ridership would remain at 2,220 per day, but boardings on the shortened Route 57 would decrease to 4,030 per day, including 1,910 transfers with the A-line. Total boardings would then be 11,360, or 6.0 percent less than the base case. Most of the decrease would be due to the imposition of the transfer with its accompanying longer wait times (in this case at Union Square), resulting in a loss of 2,330 existing trips, which would be only partially offset by other gains.

3.2.3 Ridership Impacts of Alternative Design Options

3.2.3.a Government Center Inner Terminal

Such an extension would result in an increase in surface ridership of two percent or from 60 to 260 surface-to-subway trips per weekday. The impact on subway ridership would be greater: the previously reported increases in subway ridership would increase by 50 percent, or from 520 to 630 trips per day, depending on the alternative.

3.2.3.b Signal Pre-emption

No perceptible increase in ridership would result from this measure. Only signals with relatively low cross-street traffic volumes could be pre-empted. Thus, little potential trolley delay would be obviated. For an average one-way trip between Watertown Square and Kenmore Station that takes 24 to 31 minutes, depending on the time of day, only 36 seconds of travel time would be saved. This would not be enough to induce significant ridership as it represents only a two to two-and-a-half percent savings in travel time for the average passenger trip, depending upon the time of day.

3.2.3.c Trolley Reservations

Ridership increases from reservations would be modest. Only peak-period service would be speeded because off-peak traffic volumes are not high enough to slow service in the first place. In the AM peak, average operating speeds between Packard's Corner and Brighton Center could be increased from 10.4 mph to 12.8 mph, for a travel time savings of 48 seconds, or 2.6 percent. Similarly, in the PM peak, speeds could be increased from 10.0 mph to 12.8 mph, resulting in a time savings of 106 seconds per one-way trip, or 5.9 percent. Using an elasticity of -0.39, probable

ridership increases for Alternative 2 for the AM and PM peaks would be 2.0 and 2.3 percent, respectively.

3.2.3.d Subway Tunnel

Assuming a half-mile tunnel without stations under Brighton Center and using observed acceleration and deceleration characteristics of the Boeing LRV's and a maximum speed of 50 mph, the average operating speed through the tunnel would be 29.0 mph and the average running time would be 62 seconds. For Alternative 2, this would represent a time savings of from 93 to 134 seconds, depending on the time of day. Factored into the running time for the entire Watertown to Kenmore surface alignment and using elasticities of from -0.39 to -0.74, ridership increases of from 2.2 to 4.9 percent could be expected at various times of the day.

3.2.3.e Impacts of Pre-emption, Reservations and Tunnel

If all three of the trolley priority schemes were employed, one-way running time could be reduced by approximately nine to 15 percent, depending on the time of day. Resulting ridership increases for Alternative 2 would range from four percent in the school peak to 6.6 percent in the midday and evening periods.

3.2.4 Reasonableness of Demand Estimates

In order to test the reasonableness of the demand estimates, surface-to-subway ridership estimated for the A-line was compared to that for other Green Lines.

On the B, C and D Green Line surface branches, about 75 percent of all inbound riders travel into the subway to points east of Kenmore Station. In contrast, only about 27 percent of present Route 57 bus riders transfer to the subway at Kenmore Station. Taken at face value, these results suggest a significant loss of potential riders from Route 57 due to the fare differential and the required transfer at Kenmore. However, more detailed analysis reveals that most of the "missing" surface-to-subway riders on Route 57 are accounted for by diversions to the Watertown and Brighton Center express buses on the Mass Turnpike, or to parallel sections of the B-line.

As distance from the subway increases along a surface line, the proportion of surface trips into the subway declines. This further explains why Route 57 has a relatively small number of surface-to-subway travellers: the route is long, with its outer end 5.5 miles from the subway at Kenmore. Additionally, east of Packard's Corner where the proportion of subway trips to total boardings should be

highest, the B-line, rather than Route 57, serves passengers who want to go into the subway. This further reduces the overall proportion of subway riders on Route 57.

When estimated A-line ridership for Alternative 2 is compared to ridership on the B-line along comparable segments, it becomes clear that the surface/subway splits on both are consistent and that, therefore, no major ridership sources were overlooked. Oak Square on the A-line and Boston College on the B-line are both approximately four miles from Kenmore Station. Of the AM peak-period boardings on the A-line segment between Oak Square and Packard's Corner, 61 percent are estimated to travel into the subway to points east of Kenmore Station. On the B-line segment between Boston College and Packard's Corner, the figure is 77 percent. However, these figures do not account for the shifting of passengers that would occur between the two lines. (See Appendix A, Attachment A3 for an explanation of this shifting.) When these shifts are accounted for, surface-to-subway ridership on the A-line would represent 71 percent of the total AM peak ridership; that on the B-line would represent 72 percent.

Refer to Appendix A, Attachment A3, for more information about this reasonableness test.

3.3 COST

Significant findings from the cost analysis are as follows:

- Total variable operating costs for all six basic trolley alternatives would exceed those for the base case bus alternative by 0.2% to 42% or $6,800 to $1,301,500.

- The most expensive trolley alternative, on the basis of annual variable operating costs, would be #5, (Brighton Center to Park Street). Even though the A-line component of it would be relatively short, substitute bus and Route 301 costs would become significant.

- Subway operating costs represent from 16% to 25% of total operating costs for the trolley alternatives. If they are netted out, then the surface portions of three trolley alternatives would be more expensive, in terms of annual variable operating costs, than the bus alternative: by 2 to 20%. The surface portions of the other three trolley alternatives would be 8% to 25% less expensive to operate than the bus alternative. (In order to net out subway costs, units of service were calculated separately for the subway and the surface.)

• Capital costs for all six basic trolley alternatives exceed those of the base case bus alternative. Using the interest rate of 6.9%, annualized non-federal capital costs for the basic trolley alternatives would be 36% to 390% higher than those for the base case bus alternative. The former would range from $269,000 to $886,000, while the latter is estimated at $197,000.

• Vehicle costs represent 100% of the bus alternative costs and from 65% to 93% of the trolley alternative costs, when both trolley and replacement bus costs are included.

• Trolley vehicle costs alone would account for 50 to 70 percent of the costs for those alternatives.

• Non-federal present value capital costs for additional trolley priority schemes would range from a relatively modest $41,600 for the most expensive signal pre-emption scenario to a substantial $6.7 million for a subway tunnel.

3.3.1 Operating Costs

The information provided below can also be seen in more detail in Appendix B.

3.3.1.a Bus Alternatives

The total annual variable operating costs of the bus only alternatives were estimated to be $3,083,400. (Costs would be unaffected by provision of a free transfer at Kenmore because patronage would not increase enough to warrant more service.) Of that, Route 57 costs $2,168,500 to operate and Route 301 costs $914,900.

3.3.1.b Trolley Alternatives

Total annual variable operating costs for trolley alternatives were estimated to range from $3,090,100 to $4,384,800. All would be more expensive than the base case by 0.2 percent to 42 percent. Total costs are not correlated with the length of the A-line included in each. That is, the most costly alternative is projected to be #5, (Brighton Center to Park Street). This is so because 51 percent of the costs of the alternative would be for relacement local service and Route 301 service, and these costs would more than make up for the lower costs incurred on the A-line itself. Similarly, Alternative 6, (Union Square to Park Street), is projected to be the second most costly trolley alternative.

Surface A-line variable operating costs would represent from 80 percent of total variable operating costs in the Watertown to Park Street alternative to 28 percent in the

Union Square to Park Street alternative. The subway portion of variable operating costs would range from 16 percent of the total in both the Brighton Center and Union Square alternatives to 25 percent in the Oak Square (with no 301 service) alternative.

If these subway variable operating costs are netted out of total costs and only surface A-line and bus costs are considered, then half the trolley alternatives appear less expensive than the bus alternative. Only two would experience surface variable operating costs greater than those for the bus alternative; the other three would be 8 to 25 percent less expensive. While this is an interesting result, it must be kept in mind that the foundation of the demand estimates assumes that A-line service would operate all the way through the Central Subway to Park Street; therefore, the subway variable operating costs would need to be incurred in order to realize the amount of demand projected. Furthermore, since A-line cars would not be run at frequencies such that great numbers of subway travellers could fit on them, in addition to those travellers coming in from the surface, benefits to subway users would be small. Thus, allocating any but minor costs to the Central Subway would be inconsistent.

As one would expect, annual variable operating costs for substitute bus service are projected to increase as the A-line itself becomes shorter. These costs would range from $283,300 in the Oak Square alternative to $1,393,200 in the Union Square alternative. In the former, these costs would represent 8 to 9 percent of total alternative variable operating costs, while in the latter, they would represent one-third of the costs.

For two of the three alternatives that specify retention of Route 301, variable operating costs would be the same as in the base case. In the Oak Square (shortened 301) alternative, the Route 301 costs would decrease by 18 percent to $747,900.

3.3.2 Capital Costs

The findings summarized below are also presented in depth in Appendix C.

3.3.2.a Bus Alternatives

Using an interest rate of 6.9 percent, the present value non-federal cost of the bus alternatives would be $2.3 million and the annualized cost would be $197,400. These costs would be composed solely of bus vehicle costs. These were assumed to total $141,708 per bus, based on the most

recent MBTA purchase price of RTS-II buses. This assumes no change in the required bus fleet size in future years.

3.3.2.b Trolley Alternatives

Costs for trolley alternatives were separated into vehicle acquisiton, right of way and Yard, and optional priority scheme costs. Total non-federal present value costs for these alternatives, net of priority schemes, would range from $10.4 million for the Watertown alternative to $3.2 million for the Union Square alternative. On an annualized basis, these costs would range from $886,000 to $269,400.

Vehicle acquisition costs, chiefly for trolley vehicles, represent the major component of these alternatives. At a purchase price of $1,060,000 per trolley, the present value non-federal cost of trolley vehicles would range from $6,784,000 to $2,120,000. Alternatives 4a through 6 include bus service as well, and the present value non-federal costs of buses for these would range from $1,080,100 to $83,100. Total non-federal vehicle acquisition costs for these alternatives would represent from 66 to 93 percent of total non-federal costs.

Based on information provided by the MBTA, present value right of way and Yard non-federal costs for the full Watertown to Park Street alternative would be $3,558,000. Non-federal right of way and turn around costs for the five shorter alternatives would range from $2,654,000 for the Newton Corner alternative to $224,000 for the Union Square alternative. (These costs decrease with shorter alignments, but they are not simply proportionate to mileage: they were based on actual right of way conditions on various segments of the line.) Included in these costs are those for wire and poles which would range from $798,000 for the Watertown alternative to $84,000 for the Union Square alternative.

CTPS, through a field inspection, found that the right of way costs estimated by the MBTA would actually represent a minumum required cost to restore revenue service to the line (See Section C.8 of Appendix C). The tracks, poles and wires are fairly deteriorated and much rehabilitation work would be necessary. No alternative costs were developed on the basis of the inspection; the above costs were retained for use, but with the understanding that they are lower-bound costs.

Costs for optional priority schemes would vary considerably. A subway tunnel under Brighton Center would cost a total of approximately $17.2 million of which $6.9 million would be non-federal. Reservations would be much less costly: the marginal cost for them, above track, wire and pole costs would be $481,000, non-federal. Signal pre-

emption would cost from $41,600 for the Watertown alternative to $7,000 for the Union Square alternative, non-federal.

If the federal/non-federal shares of capital costs were assumed to be 80/20 instead of 60/40, the non-federal costs of the trolley alternatives would decline slightly relative to the bus alternatives, but the latter would still be the least costly.

3.4 REVENUE

- Annual passenger revenue, at $2.07 million, would be highest for the base case bus alternative despite that two of the trolley alternatives would have higher ridership. It would exceed that from trolley alternatives by 10 to 36 percent or by $197,000 to $547,000, depending on the alternative.

- The bus alternative would have the highest revenue because MBTA fare policy dictates that the average fare would be lower on the A-line than it is on the buses currently.

- Trolley annual passenger revenue would range from a high of $1.87 million for the Watertown alternative to a low of $1.52 million for the Oak Square without Route 301 alternative.

The findings listed below are also contained in Appendix D in greater detail.

3.4.1 Revenue From Bus Alternatives

Alternative 0 (Base Case): Annual revenue generated currently is $1.6 million on Route 57 (and the Green Line from transferees) and $461,000 on Route 301, for a total of $2.07 million.

Alternative 1 (Free Kenmore Transfer): With this alternative, 3136 of 10,339 riders would utilize the free transfer at Kenmore, generating $428,000 in revenue on the paid portion of the trip. Route 57 riders not transferring would generate $879,000 in revenue. Route 301 riders, as in Alternative 0, would generate $461,000 in fare revenue. Total revenue for the alternative would be $1.77 million.

The free transfer would attract an additional 472 trips, generating $58,000 in new revenue. However, the free transfer given to existing riders would amount to a loss of $357,000 in existing revenue, for a net loss of $299,000.

3.4.2 Revenue From Trolley Alternatives

Alternative 2 (Watertown - Park): Revenue for this alternative would total $1.9 million, or $197,100 (9.5 percent) lower than the base case. This would occur in spite of an 18 percent increase in overall ridership, and would be due to the lower average fare that would be charged on the A-line, based upon current MBTA fare policies.

Alternative 3 (Newton Corner - Park): Revenue would total $1.68 million ($1.5 million surface A-line, $175,000 subway increase), or 18.5 percent lower than the base case. As in the previous alternative, lower fare revenue would be entirely attributable to the difference in fare structures between Green Line service and bus service, and would occur in spite of a 6.6 percent increase in passenger trips.

Alternative 4a (Oak Square - Park, No 301): With this alternative, ridership would decrease 1.5 percent, and revenue would decrease 26.5 percent to $1.52 million ($1.21 million A-line surface, $136,400 substitute bus, and $165,500 subway increase). The revenue decrease would be due to the difference in fare structures, and to a decrease in the number of trips made into the subway from west of Oak Square. (The decrease in trips would result from relocation of the transfer point to Oak Square where the transfer time would be significantly increased.)

Alternative 4b (Oak Square - Park, Shortened 301): For this alternative, due to the continuation of Route 301 to Oak Square, revenue would be slightly higher than for Alternative 4a, even though ridership would be slightly lower. This would be due to the number of riders who would continue to ride Route 301 in spite of the higher fare. Total revenue for the alternative would be $1.61 million ($1.0 million A-line surface, $130,600 substitute bus, $308,600 Route 301, and $154,700 subway increase), or 21.9 percent lower than current revenues. As with all other trolley alternatives, most of the revenue loss would be due to differences between Green Line and local bus fares and to a reduced number of trips from west of Oak Square.

Alternative 5 (Brighton Center - Park): Revenue for this alternative would be higher than for Alternatives 4a and 4b in spite of lower ridership. This would occur due to the relatively short length of the A-line, which would require a significant number of riders to transfer at Brighton Center. The accompanying transfer charge and the higher round trip fare for trips into the subway (75 cents in, 60 cents out, versus 60 cents both ways for transfers to the subway at Kenmore) would offset much of the loss caused by the lower round trip surface fare. Revenue for this alternative would be $724,400 on the surface A-line, $292,600 on the substitute

bus service, $460,700 on Route 301, and $151,100 from the subway increase, for a total of $1.63 million, 21.2 percent lower than the base case.

Alternative 6 (Union Square - Park): With this alternative, the surface A-line would also be short enough so that a large percentage of riders would have to take the substitute bus to get to it. As a result, these riders would continue to pay two fares, therefore reducing the revenue loss caused by the difference in mode fare structures. However, the transfer point at Union Square would be more inconvenient than at Brighton Center and would force more riders to transfer. This would reduce overall ridership and, hence, total revenue to $1.59 million.

3.5 GREEN LINE IMPACTS

The major findings of the impact analysis are as follows:

- With present and proposed levels-of-service on the B-line, there is still capacity for A-line cars on the Commonwealth Reservation.

- With present and proposed levels-of-service on the four lines using the Central Subway, there is still capacity for A-line cars.

The following findings are also described more fully in Appendix E.

3.5.1 Interaction With B-line

Restored A-line service would use the surface tracks of the existing B-line for about one mile. No signal system exists there, so trains are spaced visually at a minimum of about 15 seconds. The levels of service being analyzed for the A-line would imply that A and B-line trains could both use the shared surface tracks without creating any capacity problems. In fact, both did so until 1969 without problems. One consideration is that equipment operating presently draws more power than that used in the past, but planned improvements to the power system should provide sufficient power for all cars.

3.5.2 Interaction With Other Lines in the Central Subway

The restored A-line would share nearly two miles of the Central Subway with the B, C and D lines, and one mile with the E-line. This would be a return to the situation that existed prior to the A-line's discontinuance. Since then, there have been no major changes in the signal system that

would affect capacity. The number of trains on each of the existing four lines is currently less than or equal to 1969 frequencies.

Theoretical analysis, combined with actual operating experience, indicates that the Central Subway begins to show unacceptable delays if more than about 70 trains per hour per direction are operated.[6] Based on current schedules and planned improvements, and allowing for restoration of full E-line service, it appears that there would still be capacity available for A-line trains in the subway.

One immediate obstacle to operation of more trains in the subway is an inadequate electric power system. Equipment now used on the Green Line has significantly higher power consumption per car than the equipment used when the A-line was in operation. However, improvements currently planned or underway should correct this deficiency.

A study of the entire Green Line now being conducted by CTPS will provide further information on the sources of potential capacity constraints, and possible strategies for dealing with them.

3.6 TRAFFIC IMPACTS

The major findings of the traffic impact analysis are as follows:

- Substituting trolleys for buses would degrade traffic flow at signalized intersections in Allston and Brighton, given current conditions.

- A subway tunnel of the type proposed would eliminate the negative traffic impacts of trolleys at three out of eleven signalized intersections on the Allston/Brighton portion of the trolley alignment.

- Reservations would decrease roadway capacity considerably on Cambridge Street and to a lesser, but still significant, extent on Brighton Avenue.

- Signal pre-emption would probably have a minor negative effect on cross-streets, as specified.

- Removal of Route 301 buses from downtown Boston streets would have an imperceptible beneficial impact on traffic.

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[6] See, for example, EOTC memo, "Central Subway Capacity," K.J. Belovorac, June 10, 1975.

• The impact of operating trolleys through Newton Corner is unclear. Certainly, several safety and logistical issues would have to be dealt with.

More information about the following findings can be found in Appendix F.

3.6.1 Allston and Brighton Traffic Impacts

3.6.1.a Trolley Impact on Intersections

It was found that, at the case-study intersection of Washington Street with Market Street and Chestnut Hill Avenue, a Route 57 bus currently has an impact on PM peak hour traffic equivalent to 1.7 passenger cars in both the west and eastbound directions. However, it was found that a trolley vehicle, under the same circumtances, and loaded according to estimated demand, would have an impact equivalent to 7.0 to 10.5 passenger cars in the westbound direction and 5.0 to 5.8 passenger cars in the eastbound direction.

The difference between the bus and trolley passenger car equivalents is due to there being more passengers per vehicle boarding and alighting the trolleys than the buses (due, in turn, to four to six fewer vehicles per direction per hour serving an equal or greater number of passengers at the intersection), and due to trolleys having to stop in through-traffic lanes to serve passengers while many buses can pull over to the curb lane. These differences were found to exist notwithstanding that individual passengers can board and alight a trolley more rapidly than they can a bus.

The analysis found that when the differences in passenger car equivalents were added to existing traffic volumes, the intersection's level of service on the Washington Street approaches declined from C to D in all but one alternative. In other words, the trolleys were projected to degrade the operation of the intersection to a greater extent than buses now do.

Measured in terms of what the average motorist on Washington Street would encounter, it was projected that the amount of time that the motorist would be delayed at the intersection would increase by two to five seconds. Current average stopped delay per vehicle is 23 seconds westbound and 25 seconds eastbound, so in terms of percentages, a westbound motorist's delay would increase eight to 20 percent, and an eastbound motorist's delay would increase nine to 22 percent.

It must be stressed that these are averages and that although an added delay of two to five seconds over the hour may sound minor, the motorists who arrived at the

intersection behind a trolley would experience a perceptible increase in delay. Additionally, to the extent that these motorists encountered trolleys at other signalized intersections during the course of their trips, their total travel delay would increase.

Something approximating the calculated difference between a bus and a trolley's impact on traffic would likely be perceived at other signalized intersections in Allston/Brighton as well. However, without precise information about the intersections, the impacts cannot accurately be estimated. It is very likely that impacts elsewhere would not be any more noticeable. The Washington and Market/Chestnut Hill intersection is among the heavier travelled and trolleys there would be particularly slowed down due to having to serve many Route 301 passengers, if that route were eliminated.

Also, impacts at non-signalized intersections and mid-block trolley stops would be less noticeable than those projected for Brighton Center because the signalized intersections control the capacity of the roadway system in this area and, therefore, trolleys stopping near them would affect capacity much more than if they stop elsewhere.

3.6.1.b Impacts of Trolley Priority Schemes

Subway Tunnel

A subway tunnel under Brighton Center would eliminate trolley traffic from three out of eleven signalized intersections in Allston/Brighton. Two of these three - Washington and Market/Chestnut Hill as well as Washington and Cambridge/Winship - would be noticeably affected by trolley traffic in the absence of a tunnel. Thus, the tunnel would relieve some of the potentially most serious trolley/automobile conflicts that would occur.

Average stopped delay per vehicle at the study intersection of Washington and Market/Chestnut Hill would decrease by approximately 2.0 seconds on the Washington Street approaches if Route 57 buses were removed from the intersection, and the difference between no transit vehicles at all and trolley vehicles going through the intersection would be 3.0 to 7.0 seconds.

Reservations

Due to time and data limitations, the capacity loss to automobiles that reservations would entail could not be calculated. However, casual observation of the alignment indicates that some capacity loss would certainly occur. It would be more or less severe, depending on the location.

The most severe capacity loss would occur on the Cambridge Street reservation near Union Square and Brighton Center. In these locations, the actual roadway width is narrower than at other places and on-street parking reduces effective roadway width considerably. What is now roughly one and a half through lanes per direction, including the track right of way, would become one narrow through lane per direction. With on-street parking and snow banks, very serious constrictions of vehicular traffic could occur.

Between Warren and Gordon Streets, effective roadway width is wider, so capacity loss would be less severe. One fairly wide through lane per direction would be left with a reservation.

Brighton Avenue could accomodate a reservation more easily than much of Cambridge Street. In fact, a reservation existed there until the late 1940's when it was eliminated in order to increase the capacity of the road. However, the impact on traffic of a reservation would still be quite noticeable. Two through lanes per direction would be reduced to one and a half on this heavily travelled artery. Here too, on-street parking exists and thereby reduces the effective roadway capacity, but it is assumed that banning parking would not be a realistic option.

It is questionable whether there would be any advantage to a Brighton Avenue reservation. The tracks are offset toward the median enough and the roadway is wide enough that vehicular traffic generally does not encroach on the tracks. Aside from passenger safety benefits, and less exposure of trolley vehicles to collision accidents, it appears that much more would be lost with a reservation than would be gained from the perspective of all road users - transit and non-transit alike.

Signal Pre-emption

The impacts on traffic from signal pre-emption would probably be minor because trolley volumes would not be high and it is assumed that cross-streets with high traffic volumes would not pre-empted due to the unacceptable delays that would be created. Six intersections were deemed pre-emptable on the Allston/Brighton portion of the alignment:

- Washington at Brock/Lake Streets
- Washington at Foster
- Cambridge at Sparhawk/Warren Streets
- Cambridge at Eleanor
- Cambridge at Gordon
- Brighton Avenue at Linden

The effect of signal pre-emption would be to transfer green time, hence capacity, to the main street from the cross-streets. Assuming 12 trolleys per hour per direction and assuming that 10 seconds of green time per trolley vehicle would be shifted from each cross-street, then each cross-street would lose 120 seconds per hour or 11 to 15 percent of its current green time, depending on the intersection. The overall impact would be that some traffic would be delayed more and some traffic on the main street approaches would be delayed less.

3.6.2 Boston CBD Traffic Impacts

There would be an imperceptible improvement in CBD traffic along the Route 301 alignment if that route were eliminated. Route 301 is one of five routes operating over the same downtown streets. In the AM peak-period, there are 26 Route 301 trips out of a total of 107 express bus trips over these streets. In the PM peak-period, the comparable figures are 19 and 90. In the PM peak-period, all buses represent from three to 26 percent of the intersection approach volumes on the alignment. Route 301 buses alone represent only one to four percent of the approach volumes.

Thus, Route 301 buses represent a very small percent of the existing traffic on the alignment. Moreover, all intersections, except one, were observed to operate well in both peak periods: all traffic cleared each intersection in one cycle. (Federal and High is adversely affected by queues forming to enter the City of Boston parking garage.) Therefore, the removal of Route 301 buses would not remove a "critical" portion of traffic that would mean the difference between an intersection working or failing.

3.6.3 Newton Corner Traffic Impacts

It was felt that trolley tracks would need to be routed around the rotary so that trolleys would flow with vehicular traffic. Operating them southbound over the bridge would cause them to run counter to vehicular traffic. Even though this was the case in the 1960's, higher traffic volumes now would argue against reinstituting this routing. Clearing the bridge of traffic to let trolleys pass through, or even just diverting traffic from the tracks through the use of curbing, might cause already long peak-period queues on the Mass Pike off-ramps to lengthen even more and degrade safety on the Mass Pike to an unacceptable level. In fact, routing tracks around the rotary was the design used in costing the line due to it being much less expensive than an elevated line or a subway tunnel.

Using the difference between bus and trolley passenger-car-equivalents (PCE's) that had been calculated for Brighton

Center, and adding this difference to the existing PM peak traffic volumes, showed that the percentage increase in equivalent passenger car volumes in Newton Corner would be less than one percent. This is not to say that trolleys would not affect the rotary differently from buses, though. The analysis did not account for the level of performance of the rotary now or estimate what it would be with trolleys as was done in Brighton Center.

Traffic volumes are high in Newton Corner but roadway capacity is also high. If trolleys were routed to minimize traffic conflicts, the probable impacts of them on the performance of the rotary would be less than their impacts in Brighton Center. This is because more space would exist physically to manuever around stopped trolleys. However, the traffic conditions in the area appear, from casual observation, to be somewhat unstable and it is conceivable that introducing trolleys there could cause major problems. Without a rigorous analysis, it is difficult to make a definitive statement. For one thing, the greater length of trolleys over buses could present a problem if northbound trolleys across the bridge were stopped in the Center/Park Street intersection due to upstream delays.

One drawback to routing the tracks around the rotary is that it would introduce more trackage onto the roadway and existing tracks are deemed safety hazards by many.

Regardless of the routing used, passenger safety would be an issue in Newton Corner. Trolleys would have to be routed such that they could servce passengers near the curbs. This would cause bus/trolley conflicts unless the trolleys were stopped away from bus stops.

If a proposed transportation center in Newton Corner were to become a reality, the trolley line would be able to tie into it well. In fact, it would then become sensible to terminate the trolley at Newton Corner, rather than elsewhere, because of the benefits of having mode-transfer opportunities and because the Transportation Center would provide a turn around facility for the trolley.

4 CONCLUSIONS

Based on a comprehensive examination of the technical merits of seven different service alternatives for the Watertown/Newton Corner/Allston/Brighton transit corridor, several issues become clear. Other issues remain unclear and must await decisions by MBTA policy-makers. The following discussion is intended to frame all of the issues in as concise a fashion as possible.

4.1 BUS VERSUS TROLLEY SERVICE

The major conclusion of the analysis is that continuing to serve the corridor with existing bus services would be more cost-effective than restoring trolley service. None of the trolley alternatives would result in a deficit per passenger as low as that of present service, nor would any of them cover as great a share of their variable operating costs as do present services. The bus service in the corridor is very efficient in that it covers 67 percent of its variable operating costs. (Route 57 alone has a revenue/variable operating cost ratio of 116 percent) On this basis, retention of present bus services is the most cost-effective option available.

Trolley Alternatives #2, Watertown to Park Street, and #3, Newton Corner to Park Street, would increase overall transit ridership in the corridor, but at a high cost. In Alternative 2, the cost for attracting each new user, in terms of the annual MBTA operating deficit (exclusive of capital costs), would be $930; in Alternative 3, the cost would be $2,645 per user. Stated differently, the respective costs for Alternatives 2 and 3 would be $1.60 and $4.50 per new user trip.

Moreover, experience shows that most new users of a transit service in a highly transit served region like Boston would come from existing services. So, even though two trolley alternatives would generate more ridership in the corridor under study, many would likely be diverted from existing MBTA services not explicitly considered in the analysis.

The fact that restored trolley service would degrade vehicular traffic conditions along much of its length

represents an additional argument for retaining present bus services. The precise impacts were not always able to be estimated, but it is clear that trolley vehicles on shared rights of way in this corridor would increase problems above those created by the current buses. In addition, restored trolley service with the accompanying elimination of express bus 301 would not improve downtown Boston traffic flow to any perceptible degree.

Some other suspected benefits of restoring A-line trolley service would simply not occur. For example, some have argued that the introduction of A-line service would relieve congestion on the B-line. However, although some current B-line riders would prefer to use the A-line, there would be insufficient capacity for such diversions without extra A-line service above that assumed in the cost analysis. Relief of B-line congestion could be provided at less cost by running more B-line cars.

Some have argued that subway costs should be eliminated from the analysis of trolley alternatives due to the fact that the benefits of operating A-line trains in the Central Subway accrue to all subway riders, so for consistency, subway costs for the service should not be allocated solely to the A-line. Ignoring these costs does, indeed, lessen the cost difference between trolley and bus somewhat, but not enough to make trolley service less expensive than bus service. Furthermore, benefits to Central Subway riders from operation of A-line cars would be so limited that most or all costs of A-line service within the subway would be properly chargeable to the A-line.

It is important to bear in mind that the major cost component for any of the trolley service alternatives would be the trolley vehicle acquisition cost. In this analysis, this cost was assumed to be the current cost of a Type-7 vehicle to the MBTA. To the extent that the true "opportunity" cost of vehicles for the A-line were deemed to be less than this, the difference between the bus and trolley alternatives would lessen. However, even if the trolley vehicle acquisition cost were assumed to be half of that used, the basic conclusion that the bus alternative is less expensive would still hold.

It should also be emphasized that MBTA fare policy would imply that the average A-line fare would be less than the average bus (or bus-to-Green Line) fare paid currently by corridor travellers. This ensures that, notwithstanding higher total ridership in two trolley alternatives, annual passenger revenue for the bus alternatives will exceed that for the trolley alternatives. However, even when just the total gross cost per passenger is considered, the bus alternatives are less costly.

Finally, whether the net costs involved in the various alternatives in the study corridor are in line with subsidy costs elsewhere in the MBTA system will continue to be an issue. This analysis does not address that issue; it is left to MBTA policy-makers to do so.

4.2 RELATIVE MERITS OF TROLLEY ALTERNATIVES

A-line service would not create significant problems for other Green Line branches. If it were to be restored, though, several of the alternatives analyzed would not merit serious consideration. Any A-line service terminated short of Newton Corner would drive users away from corridor transit services instead of attracting users onto the services. This would occur because a major portion of the riders currently using Route 57 are travelling between points that are toward either ends of the route. Thus, a short trolley line would force these travellers to transfer from a subsitute local bus to the A-line at some intermediate point in their journeys. This forced transfer would then drive many people from the corridor services being provided.

Additionally, the shorter alternatives - Oak Square, Brighton Center, and Union Square - would not, with the exception of the last, avoid most of the major traffic problems (Newton Corner being an exception) that trolley's would create. Coupled with the fact that two of the shorter alternatives would actually be more costly than either a Watertown or Newton Corner alternative, there does not appear to be much reason to seriously consider them.

The full Watertown Square and the Newton Corner alternatives would appear to be the most sensible among the trolley alternatives. But even they are not without problems. They both assume that express Route 301 would be eliminated; thus, their relative performance is as high as it is largely because Route 301 riders would be forced onto them. In reality, it is likely that eliminating Route 301 would be an extremely unpopular move. Its riders basically like the route even though many would like to see its service improved (based on on-board surveys). So, if the route were actually retained along with trolley restoration, most of its riders would probably continue to use it and the entire performance of the trolley alternatives would decline from that projected.

Between the Watertown and Newton Corner alternatives, the former is probably the most sensible. Its financial performance is slightly better; this is largly because the marginal extra length of it along Galen Street would serve a great many more passengers. However, a drawback to the alternative is that the operation of trolleys on Galen street

would cause traffic problems obviated by terminating at Newton Corner.

Either the Watertown or Newton Corner alternatives would have the advantage of connecting with a proposed multi-modal transportation center in Newton Corner. It is not clear that such a center will be constructed, but if it were, the trolley would provide a potentially beneficial link to it.

Finally, the projected benefits of a subway tunnel in conjunction with some of the alternatives are not nearly great enough to justify the expense entailed in building it. However, signal pre-emption and possibly a reservation on Brighton Avenue might be worthwhile. Even though they would result in only modestly speedier service, neither would be prohibitively expensive.

4.3 BUS SERVICE

Between the two bus alternatives analyzed, retention of service in its present form seems most sensible. Providing a free transfer at Kenmore Station for Route 57 bus-to-Green Line transferees would not generate enough added ridership to appear worthwhile. It would only cause the MBTA to experience a higher deficit. More important, such a free transfer would in no way be consistent with MBTA fare policy, and would, as a practical matter, create enormous policy problems.